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Assessment of variation in chemical properties at different stages of various crop residues in composting

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Abstract

The enriched composts were prepared by using different crops residue along with various mineral sources. Different chemical parameters were assessed during decomposition of crop residues at regular intervals. The total organic carbon was decreased during decomposition process. At the end of composting, lower organic carbon content (24.90), lower C/N ratio (19.63) was noted in compost of 25% wheat straw + 25% shredded cotton stalk + 25% glyricidia leaves + 25% sorghum stubbles (T6). Besides, total N was also increased significantly (1.27%) in T6 during decomposition of crop residues. It is evident from the results that C: N ratio was gradually declined throughout the period of decomposition in all treatments. At the end of composting, the lowest pH (7.18) was observed in treatment (T6). Among various crop residues used for preparation of compost, composition of T6 was found best suitable.

Keywords: Compost, decomposition, residues, organic-carbon, rock phosphate

Introduction

Crop residues are generated in large quantities and constitute an abundant but underutilized source of renewable biomass in agriculture. The amount of crop residues available in India is estimated to be approximately 620 million tons. Day by day crops production is decreasing due to deterioration of soil health and imbalanced use of fertilizers. One way in which some of the problems associated with the utilization of various organic wastes can be resolved is by composting. Reuse of organic waste through composting is promoted as a primary measure to mitigate such environmental threats by developed nations. Composting is a technique which can be used to reduce the amount of organic waste through recycling and the production of soil fertilizers and conditioners. Compost is primarily used as a soil conditioner and not as much as a fertilizer because it contains a high organic content (90-95%) but generally low concentrations of nitrogen, phosphorus, potassium as well as macro and micro nutrients compared to commercial fertilizers. It is comparable to peat moss in its conditioning abilities. Areas where composting can be beneficial is in the recycling of the organic fraction of the municipal waste. It reduces as much as 30% of the volume, in the form of organic matter, entering our already overcrowded landfill sites. Furthermore the composting process, if performed correctly, transforms wet and odorous organic waste into an aesthetically, dryer, decomposed and reusable product (Knight W 1997) ^[12]. Sustainable agriculture envisages efficient utilization of agricultural waste in a way that it does not deplete the existing nutritious entities of the soil and replenish it in the long run. The overuse of chemical fertilizers and gapless recurring farming activities reportedly deteriorates soil (Komatsuzaki and Ohta 2007) ^[13]. To counteract some of these problems, composting of crop residues and their application in the arable fields is an alternative. Compost can be used as an alternative or supplement to mineral fertilizer additions. They have multiple functions in soils, ranging from immediate nutrient supply to long-standing soil organic carbon (SOC) build-up (Bhattacharyya *et al.* 2008) ^[13]. This also provides most of the essential nutrient elements, but due to limited availability and varying quality, they may not supply sufficient quantities to meet crop demand (Gentile *et al.* 2008) ^[7]. Compost contains valuable nutrients that could replace and/or supplement use of commercial fertilizers by homeowners (Bot and Benites, 2005) ^[4]. Composting is very suitable for drier areas where crop residues decompose very slowly in the field, in this situation composting provides greater yields for the farmer.

Crop residues, unused bedding materials, silage, manures, and similar on-farm materials can be used as co-compost cover materials, along with many off-farm residues and wastes. Since a mortality compost pile cannot be turned until the biodecomposition of the carcass body has been largely completed, the type and thickness of the cover and base layer materials play a key role in influencing the biodegradation of carcasses, and the development and retention of heat that is necessary for pathogen inactivation (Fonstand TA *et al.*, 2003) [6].

Composting is natural process of decomposition of organic matter by micro-organisms under control conditions. It considered as a valuable soil amendment. Farm compost is poor in P content (0.4-0.8%). Addition of P through low grade rock phosphate makes the compost more balanced and supplies nutrient to micro-organisms for their multiplication and faster decomposition. Enriched compost enhances the chemical properties of soil as well as improved physical and biological properties of soil. Composting is the biological stabilization and decomposition of organic substrates by a mixed microbial population under the condition which allow for the development of thermo-phillic temperature as a consequence of biologically produced heat. The final product of composting is stable for the storage and application to the land without adverse environmental effects. Proper composting stabilizes organics destroys pathogens and provide significant drying of the substrates. These unique conditions are achieved when optimum moisture and proper aeration are maintained. Soil microbial population, a living phase of soil is predominantly influenced by the magnitude of soil organic matter in soil and hence quantification of their abundance and the species prevailing determines the overall biological processes and soil health at large. Soil microbial activity during the process of decomposition of residues is dependent on the availability of easily degradable carbon rather than mineral nitrogen (Das, 2004) [5]. Being a microbial mediated process decomposition of crop residues is accompanied by the changes in enzymes responsible for most of this transformation. The diversity and population of soil microorganism and the enzymes produced will depend on the chemical composition of crop residues. (Sajjad *et al.*, 2002) [18]. Composting process of rice, wheat straw enriched with rock phosphate decrease the concentration of total carbon, NH₄-N, C: N ratio, bio molecules and increase the total nitrogen, soluble phosphorous, and organic acid (Formic, Citric, Lactic and Acetic acids). Detection of these organic acids may indicate their role in P solubility. The phosphor-composted produced with FYM enrichment can be considered a rich P fertilizer for increasing P solubility and crop production.

The majority of the information available on the changes of composts on quality Therefore, the aim of this study was to dynamics of Total carbon, Total nitrogen, C/N ratio, pH at different stages of decomposition of crop residues in composting.

Materials and Methods

Experimental Materials Treatments and Design

The experiment comprised of six treatments and four replications using Completely Randomized Design with different levels of rock phosphate @ 12%, PDKV decomposer @ 1 kg per ton, element sulphur @ 5% (50 kg per ton), Urea @ 1% (10 kg per ton) and cow dung slurry @

1% (10 kg per ton) in combination with Wheat straw (WS), Shredded cotton stalk (SCS), Glyricidia leaves (GL) and Sorghum stubbles (SS) was conducted in completely randomized design. The treatment structure constitute of following combinations; T1 - 100% Wheat straw, T2 - 100% Shredded Cotton Stalk, T3 - 50% Wheat Straw + 50% Shredded Cotton Stalk, T4 - 40% Wheat Straw + 40% Shredded Cotton Stalk + 20% Glyricidia Leaf, T5 - 30% Wheat Straw + 30% Shredded Cotton Stalk + 20% Glyricidia Leaf + 20% Sorghum Stubbles, T6 - 25% Wheat Straw + 25% Shredded cotton stalk + 25% Glyricidia Leaf + 25% sorghum stubbles.

The total carbon from compost sample was estimated by taking known quantities of dried samples in a pre-weighed silica crucible. The samples were kept in a muffle furnace at a temperature of 6000C for 2 hours. The crucible were later transferred to desiccators, cooled and immediately weighed to a constant weight (ash weight). The total presence of organic matter was calculated by taking difference of dry weight of samples and ash weight of the samples. Then total carbon was calculated by dividing the per cent organic matter by the factor 1.724 (Jackson 1973) [9].

$$\% \text{ Organic Carbon} = \frac{(100 - \% \text{ Ash})}{1.724}$$

$$\% \text{ Organic matter} = 100 - \% \text{ ASH}$$

Total nitrogen was estimated by using Micro Kjeldahl's method as described by Piper (1966) [17]. The extent of decomposition of organic substrate was determined by its C: N ratio. Un-decomposed substrates have wider C: N ratio and on decomposition the C: N ratio is reduced. With this view the oven dried samples were analyzed for their organic carbon and nitrogen content by using Ignition method (Jackson, 1973) [9] and Micro Kjeldahl's method (Piper, 1966) [17] respectively. pH was determined by pH meter using 1:4 to 1:5 (according to straw used for preparation of compost) straw to water ratio (Jackson, 1973) [9]. Briefly accurately weighted quantity of samples was mixed using 1:4 to 1:5 ratio. The centrifuged & the pH of the suspension was determined by pH meter.

Experimental data were analyzed by adopting standard statistical methods of analysis of variance as given Gomez and Gomez (1984) [8].

Composting Methodology

The pit method was employed for the preparation of enriched compost. The cotton residues were shredded into small pieces of approximately 2-3 cm length. For enrichment of compost, urea solution (1 percent), rock phosphate (RP) (12 per cent), sulphur (S) (5 per cent through gypsum) were added at total weight of crop residues followed by Phosphorus Soluble Bacteria and *Trichoderma viride* (1 kg ton-1). The moisture content of compost pits was maintained at 60 to 70 per cent at every seven days interval during the period of experimentation and turnings were given at 10 days interval up to 90 days of decomposition. The experiment was conducted under the shade and pits were covered with polythene to avoid excessive wetting by rains and to avoid sun light. There after 90 days of decomposition, treatment wise heaps were collected at one place and allowed for curing up to 30 days.

Sample Collection and Analysis

Four replicates of compost sampled were analyzed. The compost samples from pit collected, dried, ground and sieved by passing through sieve and then used for chemical analysis. Samples were oven dried at 70° C and ground to pass through a 20-mesh sieve size. The representative samples of each treatment were collected after 15, 30, 60, 90 and 120 days of during decomposition for determination of Total carbon, Total nitrogen, C:N ratio and pH.

Results and Discussion

Changes in chemical properties during decomposition of crop residues

Total Carbon

Total carbon content was decreased with the increase in the

Decomposition time. The results pertaining to the periodical changes in total carbon during composting prepared from different crop residues are presented in Table 1 & fig. 1. At 15 days of decomposition total carbon ranged from 34.78 to 38.73%, whereas, it varied from ranged 29.20 to 34.38% at 30 days, 28.85 to 33.25% at 60 days, 26.60 to 29.83% at 90 days and 24.90 to 27.47 percent at 120 days. The significantly highest value of total carbon (27.47%) was observed in 100% wheat straw. the lower value (24.90%) of total carbon was found in compost 25% wheat straw + 25% shredded cotton stalk + 25% glyricidia leaves + 25%. followed by 50% wheat straw + 50% shredded cotton stalk. The addition of glyricidia Leaves in combination of other crop residues resulted to lower the total carbon content at 120 days of decomposition period.

Table 1: Periodical changes in total carbon during decomposition of crop residues

Treatments		Total Carbon (%)				
		Days after decomposition				
		15	30	60	90	120
T ₁	100% WS	38.73	34.38	32.18	28.18	27.47
T ₂	100% SCS	35.28	34.35	33.25	29.00	25.65
T ₃	50% WS + 50% SCS	36.14	30.25	29.38	29.83	25.14
T ₄	40% WS + 40% SCS + 20% Glyricidia Leaves	35.48	32.20	32.05	28.63	26.44
T ₅	30% WS + 30% SCS + 20% Glyricidia Leaves + 20% Sorghum Stubbles	36.10	32.08	31.85	26.60	26.55
T ₆	25% WS + 25% SCS + 25% Glyricidia Leaves + 25% Sorghum Stubbles	34.78	29.20	28.85	27.90	24.90
SE(m)±		0.66	0.99	0.80	0.96	0.29
CD at 5%		1.95	2.94	2.37	NS	0.86

Gradually and consistent decrease in total carbon content during composting was also noticed by Manna *et al.* (2001) [15], Khan and Sharif (2012) [11]. The total carbon content decreased as the decomposition proceeds from 0 to 90 days

was noted by Banta and Dev (2009) [1], which may be due to the carbon degrading activity by microbes or due to the stimulating effect of added N on microbial activity during decomposition.

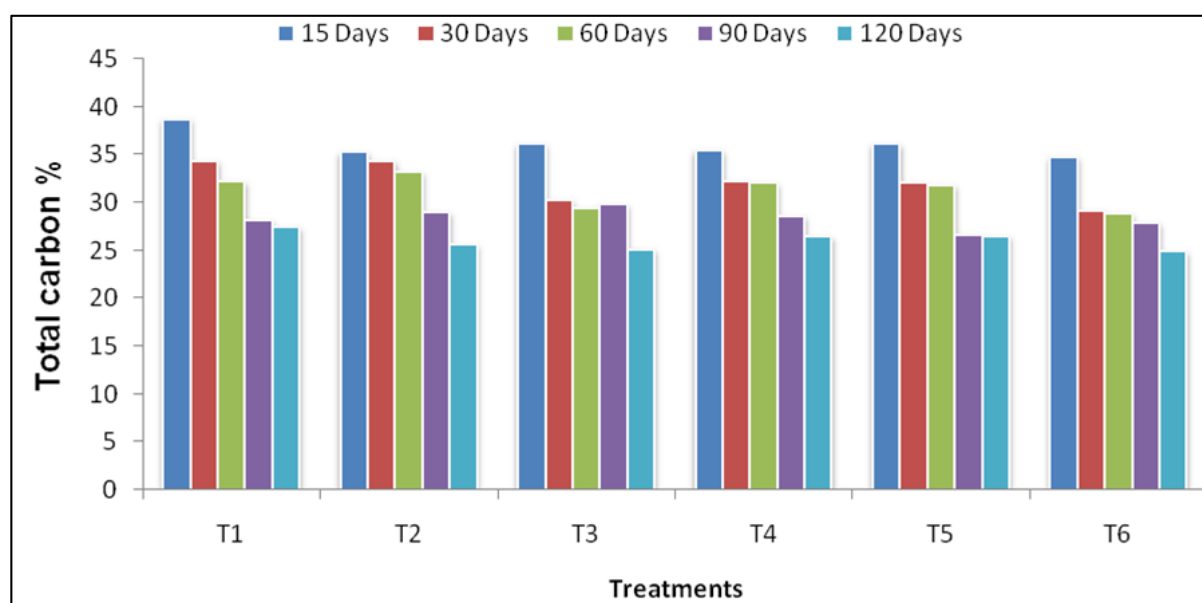


Fig 1: Periodical changes in total carbon during decomposition of crop residues

Total Nitrogen

Changes in total nitrogen content during composting of crop residues presented in Table 2 & fig.2. The decrease in total N in compost prepared from 50% WS + 50% SCS may be due to execution of glyricidia leaves during preparation of compost which contains appreciably higher quantity of N. The total nitrogen content was increased with the advancement in the

decomposition period. The results pertaining to the periodical changes in total nitrogen during composting of crop residues are presented in Table 2, The total N content at 15, 30, 60, 90 & 120 days of decomposition varied from 0.49 to 0.69%, 0.59 to 0.75%, 0.73 to 0.93%, 0.85 to 1.15% and 1.02 to 1.27% respectively among various treatment at 120 days of decomposition of crop residues.

The significantly highest value of total nitrogen content (1.27%) was found in compost prepared from 25% wheat straw + 25% shredded cotton stalk + 25% glyricidia leaves + 25% sorghum stubbles and it was found to be on par with compost prepared from 30% wheat straw + 30% shredded

cotton stalk + 20% glyricidia leaves + 20% sorghum stubbles followed by with compost prepared from 40% wheat straw + 40% shredded cotton stalk + 20% glyricidia leaves. Significantly lower total nitrogen content (1.02) was observed in 50% wheat straw + 50% shredded cotton stalk.

Table 2: Periodical changes in total nitrogen during decomposition of crop residues

Treatments		Total Nitrogen (%)				
		Days after decomposition				
		15	30	60	90	120
T ₁	100% WS	0.56	0.63	0.78	0.91	1.19
T ₂	100% SCS	0.49	0.61	0.73	0.85	1.05
T ₃	50% WS + 50% SCS	0.52	0.59	0.75	0.89	1.02
T ₄	40% WS + 40% SCS + 20% Glyricidia Leaves	0.64	0.74	0.87	1.03	1.21
T ₅	30% WS + 30% SCS + 20% Glyricidia Leaves + 20% Sorghum Stubbles	0.66	0.71	0.90	1.09	1.25
T ₆	25% WS + 25% SCS + 25% Glyricidia Leaves + 25% Sorghum Stubbles	0.69	0.75	0.93	1.15	1.27
SE(m)±		0.03	0.02	0.02	0.02	0.05
CD at 5%		0.09	0.05	0.05	0.06	0.13

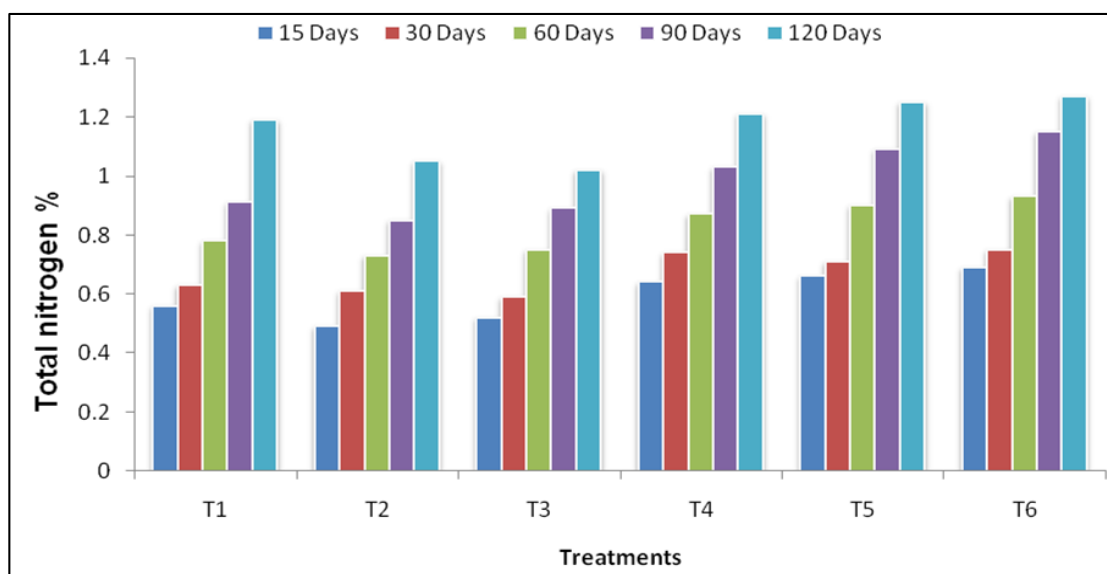


Fig 2: Periodical changes in total nitrogen during decomposition of crop residues

The compost prepared from various crop residues along with glyricidia leaves in total nitrogen content. This effect was might be due to higher concentration of nitrogen in glyricidia leaves. The results of the present investigation are in congruence with those of Manna *et al.* (2001) [15] and Khan and Sharif (2012) [11]. They found that the total N content of compost treatments were in increasing trend with increase in decomposition period. The similar findings were also reported by Banta and Dev (2009) [1]. They stated that addition of microbial inoculants in rock phosphate lead to increase in N content of mature compost and addition of rock phosphate accelerates the mineralization of N. Similarly, Sibi (2011) [19]

concluded that apparent increase in total nitrogen content in compost is not only due to enrichment but also due to the reduction in weight because of decomposition.

C: N ratio

Changes in C: N ratio was recorded at regular interval during decomposition of crop residues and presented in Table 3 & fig.3. The C: N ratio of the substrate is the most important factor in the process of decomposition. Wider the C: N ratio slower will be the decomposition. *viz.* narrow down the C:N ratio attack more rapidly by decomposing microorganisms.

Table 3: Periodical changes in C: N ratio during decomposition of crop residues

Treatments		C:N Ratio				
		Days after decomposition				
		15	30	60	90	120
T ₁	100% WS	69.50	54.30	41.30	30.44	23.04
T ₂	100% SCS	72.75	56.78	45.63	34.12	24.49
T ₃	50% WS + 50% SCS	69.97	51.27	39.30	33.42	24.77
T ₄	40% WS + 40% SCS + 20% Glyricidia Leaves	55.87	43.66	36.67	27.93	21.85
T ₅	30% WS + 30% SCS + 20% Glyricidia Leaves + 20% Sorghum Stubbles	54.90	45.18	35.33	24.36	21.24
T ₆	25% WS + 25% SCS + 25% Glyricidia Leaves + 25% Sorghum Stubbles	50.77	39.19	31.00	24.33	19.63
SE(m)±		0.68	0.41	0.65	0.83	0.91
CD at 5%		2.02	1.21	1.92	2.48	2.71

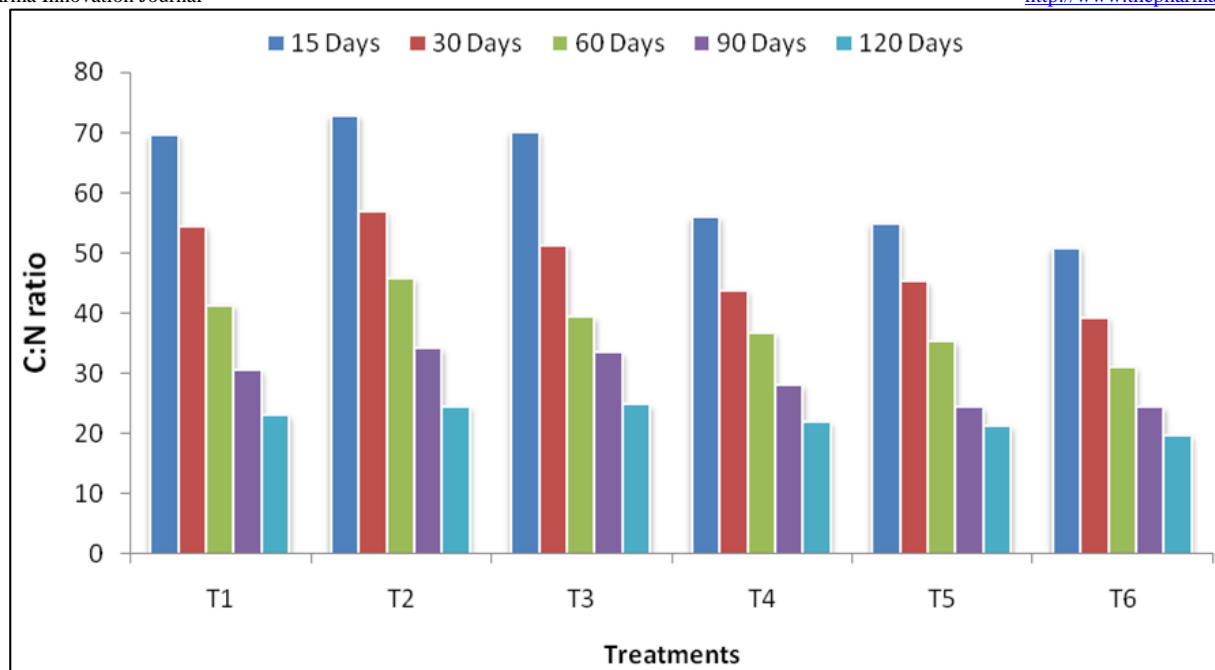


Fig 3: Periodical changes in C:N ratio during decomposition of crop residues

The C: N ratio of various crop residues used for the preparation of compost varied widely as the days of decomposition proceeds. During the initiation of composting i.e. after 15 days the C: N ratio was wider. The C: N ratio of the various treatments ranged between 50.77 to 72.75 at 15 days of decomposition, 39.19 to 56.78 at 30 days, 31.00 to 45.63 at 60 days, 24.33 to 34.12 at 90 days and 19.63 to 24.77 at 120 days of decomposition respectively. The significantly highest C:N ratio i.e. 24.77 at 120 days stage was recorded in the treatment of composting prepared from 50% wheat straw + 50% shredded cotton stalk and significantly lower values (19.63) of C:N ratio was obtained in the compost prepared from wheat straw, shredded cotton stalk, glyricidia leaves and sorghum stubbles.

The decrease in C: N ratio with time span might be due to decrease in carbon content which absorbed due to loss of organic carbon through oxidation and simultaneously increase in the total nitrogen. The results are in conformity with the finding of by Banta and Dev (2009) [1], they noticed that the C:N ratio at the initiation stages of composting was higher, which was narrowed down at maturity of compost. This reduction may be due to carbon degrading activity of microbial inoculents. Khan and Sharif (2012) [11] also concluded that reach of C:N ratio with the time span might be due to escape of CO₂ after decomposition. While, mostly nitrogen remain in the system. Similar observation was reported by Hellal (2012) [10].

pH as influenced by various crop residues during periodic decomposition: The negative logarithm of hydrogen ion activity which indicates the acidity or alkaline nature of soil is usually expressed as pH value. The results pertaining to the periodical changes in pH during composting prepared from different crop residues are presented in Table 4 & fig.4. Significant changes were observed in pH values affected by different treatments. The pH controls microbial activity during the process of decomposition. During composting period the pH values remained declining irrespective of the treatments and the time span. At 15 days of composting the pH values ranged between 7.74 to 8.20 which was gradually falls and at 120 days it ranged between 7.18 to 7.49. At the end of composting, the lowest pH (7.18) was observed in treatment (T6) i.e. 25% WS + 25% SCS + 25% Glyricidia Leaves + 25% Sorghum Stubbles. The highest pH (7.49) was noted in treatment (T3) 50% WS + 50% SCS.

The present findings are in accordance with those of Singh and Amberger (1998) [20]. They pointed out that the initial pH of decomposing straw increased slightly because of addition of cow dung and rock phosphate of high CaCO₃, but it decreased gradually with decomposition of organic matter which resulted in the release of organic acids in all treatments. Similar declining trend was noticed by Kumari *et al.* (2008) [15] and Khan and Sharif (2012) [11]. Hellalet *et al.* (2012) [10] prepared rice straw phosphocompost and they stated that decrease in pH may be caused by increased production of organic acids or increased nitrification.

Table 4: Effect on pH as influenced by various crop residues during periodic decomposition

Treatments		pH				
		Days after decomposition				
		15	30	60	90	120
T ₁	100% WS	8.12	7.82	7.69	7.54	7.46
T ₂	100% SCS	8.20	7.81	7.61	7.44	7.35
T ₃	50% WS + 50% SCS	8.13	7.79	7.61	7.55	7.49
T ₄	40% WS + 40% SCS + 20% Glyricidia Leaves	7.82	7.72	7.54	7.37	7.24
T ₅	30% WS + 30% SCS + 20% Glyricidia Leaves + 20% Sorghum Stubbles	7.81	7.62	7.50	7.33	7.19
T ₆	25% WS + 25% SCS + 25% Glyricidia Leaves + 25% Sorghum Stubbles	7.74	7.61	7.49	7.24	7.18
SE(m)±		0.01	0.02	0.01	0.06	0.07
CD at 5%		0.03	0.05	0.02	NS	NS

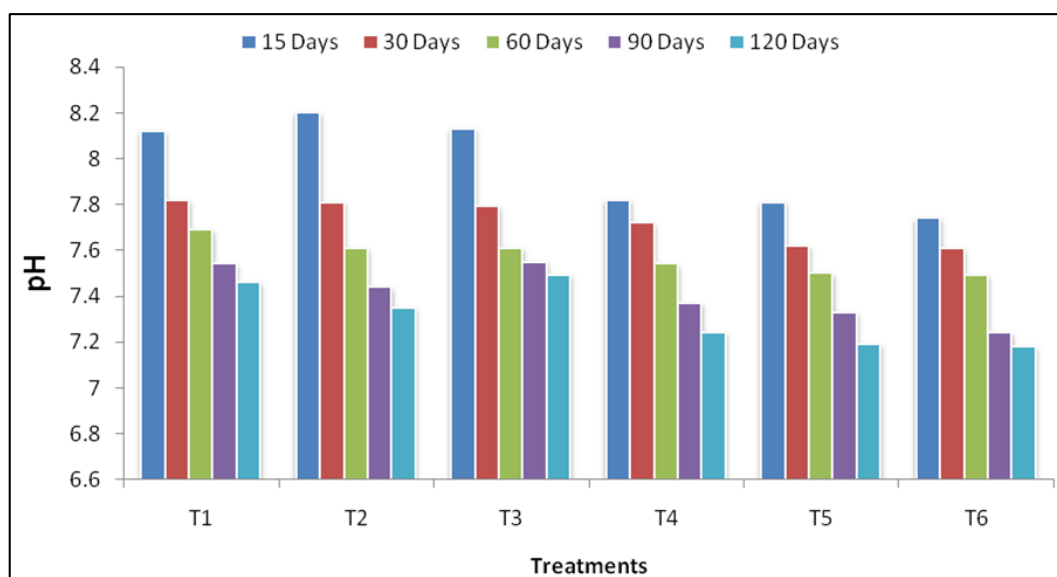


Fig 4: Periodical changes in pH during decomposition of crop residues

Conclusions

From the above study, it can be concluded that, the compost prepared from 25% WS + 25% SCS + 25% glyricidia leaves + 25% sorghum stubbles was found beneficial to increase the concentration of total N. The compost prepared from 25% wheat straw + 25% shredded cotton stalks + 25% glyricidia leaves + 25% sorghum stubbles (T₆) recorded relatively lowertotal carbon, C: N ratioduring decomposition of crop residues. The compost prepared from 25% waheat straw + 25% shredded cotton stalks + 25% glyricidia leaves + 25% sorghum stubbles (T₆) recorded relatively lower pH. This will be helpful in improving the beneficial nutrient status of soil.

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References

- Banta G, Dev SP. Field evaluation of nitrogen enriched phospho-compost prepared from green biomass of *Lantana camara* in wheat. *Indian Journal of Ecol.* 2009; 36(1):39-44.
- Bhardwaj KK, Gaur AC. The effect of humic and fulvic acid on the growth, efficiency of nitrogen fixation by *azotobacterchrococum*. *Folia Microbial.* 1970; 15:364.
- Bhattacharyya R, Kundu S, Prakash V, Gupta HS. Sustainabilityunder combined application of mineral and organic fertilisers in a rainfed soybean– wheat system of the Indian Himalayas. *European Journal of Agronomy*, 2008, 33-46. doi:10.1016/j.eja.2007.04.006
- Bot A, Benites J. The Importance of Soil Organic Matter, Key to Drought-Resistant Soil and Sustained Food Production. Foodand Agriculture Organization of the United Nations, Rome. 2005. <http://www.fao.org/docrep/009/a0100e/a0100e.pdf>
- Das DK. *Introductory Soil Science*, Kalyani Publisher., New Delhi, 2004, 293-314.
- Fonstad TA, Meier DE, Ingram LJ, Leonard J. Evaluation and demonstration of composting as an option for dead animal management in Saskatchewan. *Canadian Biosystems Engineering.* 2003; 45:19-25.
- Gentile R, Vanlauwe B, Chivenge P, Six J. Interactive effects from combining fertiliser and organic residue inputs on nitrogen transformations. *Soil Biology& Biochemistry.* 2008; 40:2375-2384.
- Gomez KA, Gomez AA. *StatisticalProcedure forAgricultural Research.* John Wiley and Sons, New York. 1984; 241-266.
- Jackson ML. *SoilChemical Analysis (Edn.-2)* Prentice Hall of India Pvt. Ltd. New Delhi. 1973; 69-182.
- Hellal FA, Nagumo F, Zewainy RM, Influence of phosphocompost application on phosphorus availability and uptake by maize grown in red soil of Ishigaki Island, Japan. *Agricultural Sciences.* 2012; 4(2):102-109.
- Khan M, Sharif M, Solubility enhancement of phosphorus from rock phosphate through composting with poultry litter. *Sarhad J Agric.* 2012; 28(3):415-420.
- Knight W Compostconvective airflow N, C conservation with passive and active aeration. M. Sc. Thesis, Agric. And Biosystems Eng. McGill University, Canada, 1997.
- Komatsuzaki M, Ohta H. Soil management practices for sustainable agro-ecosystems. *Sustain Sci.* 2007; 2:103-120. <https://doi.org/10.1007/s11625-006-0014-5>
- Kumar K. Effect of nitrogen, phosphours, sulphur and microbial inoculants on decomposition of crop residues. M. Sc. (Agri.) thesis (unpub.) Dr. PDKV, Akola, 2015.
- Kumari A, Kapoor KK, Kundu BS, Mehta RK. Identification of organic acids produced during rice straw decomposition and their role in rock phosphate solubilization. *J Plants & Soil Envir.* 2008; 54 (2):72-77.
- Manna MC, Hajra JN, Singh AB. Comparative effectiveness of enriched phosphocompost and chemical fertilizer on crop yields and soil biological activity in an alluvial soil. *Indian J Agric. Res.* 2001; 35(4):247-250.
- Piper CS. *Soil and Plant Analysis*, Hans Pub. Bombay. Asian Ed. 1966, 368-374.
- Sajjad MH, Lodhi A, Azam F. Changes in enzyme activity during the decomposition of plant residues in

- soil. Pakistan Journal of Biological Science. 2002; 5:952-955.
19. Sibi G. Role of phosphate solubilizing fungi during phosphocompost production and their effect on the growth of tomato (*Lycopersicon esculentum* L) plants. J of App. and Natural Sci. 2011; 3(2):287-290.
 20. Singh CP, Amberger A. Organic acids and phosphorus solubilization in straw composted with rock phosphate. J of Bioresourcr Tech., 1998; 63:13-16.