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Composting of organic wastes using newly developed cellulolytic microbial consortium

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Abstract

Experiment under glass house conditions was conducted to see the efficacy of newly developed microbial consortium for composting different organic substrates. During experiment period, in all the treatments, increase in temperature was recorded from the first week of composting. In majority of the substrates temperature increase was recorded upto fourth week of composting, and thereafter a gradual decline was recorded. Within 30 days there was steep increase in the bacterial and fungal population in all the treatments which continued to increase upto 120 days and thereafter a gradual decrease was recorded. While the population of actinomycetes increased in later stage and reached at peak between 120 and 150 days of composting. Test consortium was found significantly superior in reducing the decomposition time of substrates over other treatments. The reduction in composting time over control ranged from 9.65 to 23.36% in different substrates. Vegetable waste decomposed at the fastest rate (48.7 to 59.3 days) while saw dust required maximum time (179.7 to 214.3 days) for decomposition. Reduction in C:N ratio over initial was recorded in all the treatments at maturity while pH of all substrates shifted towards normal. The treatment with test consortium on different substrates recorded numerically higher mineral content over MPKV consortium and uninoculated control. Results indicated that the use of test consortium reduced the overall time required for composting besides producing the nutrient enriched compost product.

Highlights

- Test microbial consortium accelerated the rate of decomposition of substrates
- Temperature and microbial count of substrates increased from first week of composting
- Maximum reduction in C:N ratio was in substrates treated with test consortium comprised of cellulolytic fungal species
- pH of all substrates shifted towards normal at maturity

Keywords: Microbial consortium, substrates, composting, chemical parameters, maturity

Hundreds of tones of biodegradable organic waste are being generated in cities, towns and rural areas creating disposal problems. Landfill and incineration have until now been the most widely used means of solid waste disposal throughout the world. But, land filling of biodegradable waste is proven to contribute to environmental degradation, mainly through the production of highly polluting leachate and methane gas. The concept of recycling waste nutrients and organic matter back to agricultural land is feasible and desirable. Land application represents a cost effective outlet for the producers of compostable wastes and a potential cheap source of organic matter and fertilizer elements for farmers.

Composting of organic wastes is a bio-oxidative process involving the mineralisation and partial humification of the organic matter, leading to a stabilised final product, free of phytotoxicity and

pathogens and with certain humic properties (Zucconi and de Bertoldi, 1987). It serves as a mean of environmentally acceptable waste disposal on the one hand and produces organic fertilizers on the other. As a consequence of increasing fertilizer costs, fluctuating product prices and decreasing soil productivity, the farmers are shifting to the use organic material as nutrient source (Rakshit *et al*. 2009). But the availability of organic matter is also factor to put organics in use. The utilization of biodegradable organic fraction of urban wastes, cattle waste and crop residues after composting as a source of plant nutrient can solve the farmer's problem.

Microbes play a key role as degraders during the composting process, and the microbiology of composting has been studied for decades. Microorganisms that populate substrates during composting reflect the evolution and the performance of the composting process. Their metabolic paths lead to significant changes in the physical and chemical parameters of the composting substrate, and that, in turn, leads to changes in the microbial community structure. In addition, the microbial community structure is of interest because composting, if not properly managed, might sustain potential pathogenic factors and/or emit gases such as CH_4 that contribute to the greenhouse effect (Wei *et al.* 2007). At each composting stage, specific microorganisms predominate and play a primary role in the reduction and conversion of organic waste in response to temperature. The major active group of microorganisms responsible for aerobic composting is of thermophiles. Aerobic composting will proceed even in the absence of deliberate addition of thermophilic microbial inoculum. This is because native thermophiles occurring on the raw materials will be functioning as the inoculum *in situ*. However, inoculation with more efficient microorganisms may prove beneficial and make the process of biodegradation quick and economically viable.

With this background experiment was conducted to see the effect of newly developed consortium of cellulolytic microorganisms on decomposition of different organic substrates.

Materials and Methods

The consortium of cellulolytic microorganisms was developed by isolating cellulolytic microorganisms from naturally decomposing organic matter. These isolates were studied for cellulolytic activity and compatibility with each other. The highest cellulase producing microorganisms *viz*., bacterial isolate B-28 (*Bacillus* sp), fungal isolate F-13 (*Aspergillus terreus*) and actinomycetes isolate A-40 (*Streptomyces* sp.) were incorporated in the consortium. The developed consortium was tested for its decomposing ability by incorporating on six different substrates. The *in-vitro* experiment was carried out in the glasshouse of Department of Plant Pathology and Agricultural Microbiology, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (MS). The experiment was planned with 3 main treatments and 6 sub-treatments in FCRD design with three replications. The treatment details are as follows:

(a) Main treatments	(b) Sub treatments
1. Test consortium	1. Wheat straw
2. MPKV's decomposing culture	2. Sorghum straw
3. Control (uninoculated)	3. Chickpea straw
	4. Maize cobs
	5. Vegetable waste
	6. Hardwood sawdust

Wheat straw, sorghum straw, chickpea straw and maize cobs were collected from University farm, while vegetable waste and hardwood sawdust were collected from Rahuri town. The substrates were chopped into 2-3 cm pieces and filled in high density polythene bags (67 × 50 cm) with 75 micron thickness upto $^{3}/_{4}^{th}$ of total height of bags. One per cent urea solution was added to lower down the C:N ratio and better growth of microorganisms. Respective bags were inoculated with newly developed test consortium and MPKV's decomposing culture (composting culture developed by University which comprised of cellulolytic fungal species) @ 1 gm/ kg of substrate. The bags inoculated with MPKV's composting culture served as inoculated control while, the uninoculated bags served as uninoculated control. The polybags were watered frequently so as to maintain 60-65% moisture level. Turnings were given at 8, 15, 30, 60, 90 and 120th day after inoculation. Temperature of the substrates at centre of polybags was measured by hand thermometer weekly at fixed time. For initial and final pH, samples were taken in 100 ml beaker and diluted 1:10 (1 part sample in 10 parts of distilled water) and placed on shaker for 1 hr. The samples were centrifuged at 4000 rpm for 30 min. and filtered

through Whatman No.1 filter paper. pH of the suspension was measured potentiometrically using a combined glass electrode. Organic carbon content of substrates was determined by ignition method (Bremner, 1970). Total nitrogen content of the substrates was determined by modified Kjeldhals method (Piper, 1966). Total phosphorus content was estimated by following the procedure given by Jackson (1973). Total potassium content in an aliquot of tri acid mixture with suitable dilution was estimated using flame photometer (Jackson, 1973). Maturity of compost was recorded on the basis of pre-established maturity and stability parameters of compost (Ranalli *et al.* 2001; Goyal *et al.* 2005 and Raj and Antil, 2011).

Results and Discussion

Changes in temperature during composting

Increase in temperature was recorded from the first week of composting at weekly intervals (Table 1). In majority of the substrates highest temperature was recorded from first to fourth week of composting, and thereafter a gradual decline in temperature was recorded. In vegetable waste highest temperature was recorded in the first week, while saw dust required ten weeks to attain the peak temperature. Highest temperature was recorded in wheat straw and maize cobs during fourth week , while in sorghum straw and chickpea straw highest temperature was during 5th and 2nd week of composting. Slightly high temperature was recorded in the main treatment with test consortium on different substrates which may be due to the high microbial activity.

Goyal *et al.* (2005) recorded initial temperature of 28-30°C at the start of composting and highest temperature was observed at 14 days of composting which rose up to 46°C then declined gradually. Changes in the temperature at various stages of decomposition of different composting mixtures were also studied by Raj and Antil (2011). Temperature of all the composts reached maximum (53-63°C) within 4-6 days of composting and reflected rapid initiation of composting process. After 6 days, it decreased gradually but remained in thermophilic range (>45°C) up to 61-68 days, except in farm waste compost. It further decreased and reached ambient level between 109 and 115 days of composting in farm waste. Similar trend of temperature variation have been reported by Tiquia (2005), Gazi *et al.* (2007) and Himanen and Hanninen (2011).

Microbial population during composting

Within 30 days there was steep increase in the bacterial population in all the treatments which continued to increase upto 90 days in majority of the substrates (Table 2). A gradual decrease in population was recorded thereafter. Highest bacterial activity was recorded in the treatment with test consortium while lowest was in uninoculated control. The fungal population increased at a slow rate and attained its highest during 120 days of composting in majority of the substrates (Table 3). Fungal population in main treatment with test consortium and inoculated control was superior over the uninoculated control. The actinomycetes population was less during the initial stages of composting but increased as soon as the population of bacteria and fungi declined (Table 4). Highest population of actinomycetes was recorded at 150 days in majority of the substrates. The population of actinomycetes was recorded superior in the substrates with the main treatment of test consortium as compared to the control treatments. Actinomycetes were seen active during the curing phase.

Nielsen *et al*. (1997) determined the population of microorganisms at various stages of composting process. The initial count of bacteria was 1.5×10^{10} cfu/g which increased to 8.6×10^{10} cfu/g in 11th week. While the initial concentration of actinomycetes and fungi was 3.0×10^{2} cfu/g and 4×10^{2} cfu/g, which reached to 4.8×10^{5} cfu/g and 4×10^{3} cfu/g, respectively at the end of 11th week. Hassen *et al.* (2001) reported that, at the beginning of aerobic composting cycle the population of bacteria was in the range of 8.5×10^{8} and 5.8×10^{9} cfu/g waste dry weight in the different windrows studied. From sixth week the number decreased and reached to 1.8×10^{7} cfu/g in ninth week. During later cooling phase the resurgent growth of mesophilic bacteria reached to 1.8×10^{8} cfu/g. While the population of filamentous fungi remained stable until third week of composting (6.3×10^{3} cfu/g) and decreased upto 2.6×10^{3} at the end of thermophilic stage. Haritha Devi *et al.* (2009) reported that, on the first day of normal composting the population of bacteria, fungi and actinomycetes was 41×10^{6}, 15×10^{4} and 38×10^{5} cfu/g compost,

Table 1: Changes in temperature during composting of different substrates

Substrate	Consortia	Weekly Average temperature (°C)																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Wheat straw	Test	34.3	40.2	52.9	62.3	61.2	55.1	54.0	47.0	42.0	39.0	36.3	35.7	34.2	34.3	33.6	31.7	30.2	29.4	30.0	28.6
	MPKV	34.0	39.0	51.6	61.0	59.8	52.3	53.3	48.3	42.9	39.6	36.2	35.3	34.7	34.2	33.4	31.6	30.4	29.5	29.9	28.5
	Control	31.9	38.3	50.0	59.2	59.0	52.0	53.0	48.9	43.0	39.2	36.4	35.7	34.6	34.6	33.5	33.6	30.4	29.7	30.2	28.6
Sorghum straw	Test	35.9	39.0	58.0	52.0	52.2	51.7	50.1	45.6	43.0	38.6	33.7	31.7	29.8	30.2	30.1	29.7	30.3	30.5	29.7	28.4
	MPKV	35.0	38.6	56.3	51.6	51.8	51.3	49.7	45.7	43.2	38.8	32.6	31.5	30.3	30.4	30.2	29.8	30.5	30.4	29.9	28.5
	Control	35.0	38.0	55.0	51.4	52.0	51.2	49.6	45.8	43.6	39.0	33.5	31.5	30.4	30.3	30.0	28.9	30.5	30.6	29.8	28.6
Chickpea straw	Test	50.0	62.3	59.3	48.2	45.2	44.6	42.6	43.1	39.0	36.0	31.3	30.9	29.9	29.6	29.0	29.3	28.0	29.9	28.4	28.5
	MPKV	49.0	61.6	58.3	48.4	48.4	45.5	43.3	42.7	39.2	36.2	30.7	29.6	30.2	30.0	29.1	30.2	28.2	29.7	28.3	28.4
	Control	46.6	61.2	59.1	50.0	50.5	46.5	43.6	41.8	39.0	38.0	31.1	30.0	30.5	30.2	29.2	29.7	28.2	29.1	28.4	28.3
Maize cobs	Test	31.2	36.2	48.3	62.0	54.0	49.9	46.9	43.0	42.8	40.3	39.7	36.0	33.3	30.1	30.7	29.2	28.1	29.2	29.3	28.4
	MPKV	30.8	34.1	47.0	61.1	53.0	48.6	45.6	42.7	41.0	40.2	38.7	35.0	34.0	30.2	30.3	28.6	28.3	29.0	28.4	28.5
	Control	30.6	33.6	46.9	60.2	50.0	47.3	45.7	40.9	40.8	40.9	39.4	36.0	33.6	31.0	30.4	29.0	28.4	28.6	29.0	28.5
Vegetable waste	Test	59.8	48.0	37.0	33.0	32.0	31.0	30.9	30.0	30.0	29.0	29.0	28.8	29.0	30.0	28.9	29.3	28.3	29.2	29.0	28.6
	MPKV	58.3	47.2	36.0	33.0	31.6	32.0	31.3	30.3	30.0	29.0	28.8	28.8	28.7	30.2	29.1	29.2	28.4	28.9	29.1	28.7
	Control	58.0	47.4	35.9	33.3	31.2	32.2	31.4	30.4	29.8	29.1	29.0	29.0	28.5	29.6	29.0	28.7	28.4	29.1	29.2	29.0
Saw dust	Test	34.0	34.2	36.0	40.2	42.0	42.2	44.3	45.2	56.3	61.0	53.0	50.3	50.1	49.0	45.0	40.1	35.9	36.6	30.9	29.6
	MPKV	33.9	34.0	35.2	39.8	41.0	42.0	43.2	44.0	56.2	60.4	52.0	50.6	50.3	48.3	44.3	40.3	36.1	37.1	33.0	30.1
	Control	33.0	33.6	34.6	39.2	41.2	42.0	43.6	43.4	55.3	60.6	51.0	51.9	50.1	48.6	43.6	41.6	36.0	36.1	30.7	30.2

Table 2: Bacterial population during composting of different substrates

Consortia	Substrate	Bacterial population (×10^7 cfu/g of dry matter)						
		Initial*	30 days	60 days	90 days	120 days	150 days	180 days
Test Consortium	Wheat straw	14.7	23.3	36.3	39.7	38.7	32.3	29.7
	Sorghum straw	17.3	32.3	42.3	30.3	28.7	25.3	22.3
	Chickpea straw	18.3	34.3	45.3	35.0	27.0	26.3	25.0
	Maize cobs	15.3	22.3	39.7	44.3	41.3	32.3	29.3
	Vegetable waste	20.3	42.7	51.0	23.7	18.3	13.3	11.0
	Saw dust	15.0	20.0	32.0	37.3	38.7	33.7	32.3
MPKV Consortium	Wheat straw	3.3	9.3	19.3	26.3	24.3	19.3	15.3
	Sorghum straw	5.7	14.0	33.3	32.3	16.7	13.3	12.3
	Chickpea straw	2.3	7.3	28.3	26.0	17.3	15.3	13.3
	Maize cobs	4.0	12.3	23.0	28.7	29.3	23.3	20.7
	Vegetable waste	9.0	21.7	36.3	26.3	18.7	12.3	10.7
	Saw dust	2.3	8.3	10.7	17.7	19.7	23.3	21.7
Uninoculated control	Wheat straw	2.3	7.3	14.7	25.3	26.3	21.3	19.7
	Sorghum straw	4.3	12.7	29.3	26.7	19.0	13.3	11.3
	Chickpea straw	1.6	9.3	27.3	25.0	18.7	14.0	12.0
	Maize cobs	3.3	10.0	24.0	29.7	32.3	21.7	18.7
	Vegetable waste	5.0	19.7	36.7	16.7	17.3	11.3	9.3
	Saw dust	2.7	6.3	12.7	19.0	21.3	24.3	22.0
		Factors						
A (Consortia)	SE(m)±	0.35	0.52	0.59	0.66	0.57	0.60	0.63
	CD	0.99	1.51	1.70	1.89	1.64	1.71	1.82
B (Substrate)	SE(m)±	0.49	0.74	0.83	0.93	0.81	0.84	0.90
	CD	1.41	2.14	2.40	2.67	2.32	2.42	2.58
A x B	SE(m)±	0.85	1.28	1.44	1.61	1.40	1.46	1.55
	CD	NS	3.70	4.16	4.63	4.02	4.20	4.46

(*24 hrs after inoculation)

Table 3: Fungal population during composting of different substrates

Consortia	Substrate	Fungal population (×10^4 cfu/g of dry matter)						
		Initial*	30 days	60 days	90 days	120 days	150 days	180 days
Test Consortium	Wheat straw	14.0	29.7	33.7	37.7	42.3	38.7	30.3
	Sorghum straw	16.3	28.7	42.3	49.7	50.0	47.0	40.3
	Chickpea straw	16.3	34.7	47.3	55.3	53.7	51.3	41.7
	Maize cobs	15.3	32.3	49.7	56.7	53.3	49.3	43.3
	Vegetable waste	11.7	23.3	39.0	48.7	43.3	39.3	33.3
	Saw dust	12.0	22.3	37.0	45.7	52.3	48.3	39.7
MPKV Consortium	Wheat straw	16.0	28.7	30.3	38.3	43.3	38.7	36.0
	Sorghum straw	19.3	28.0	38.7	47.7	52.3	49.7	35.3
	Chickpea straw	18.7	33.3	44.0	53.0	56.0	47.7	39.3
	Maize cobs	16.7	31.3	42.7	57.7	50.7	43.3	33.0
	Vegetable waste	17.0	26.3	40.7	48.7	40.7	33.0	30.7
	Saw dust	10.3	21.7	33.3	41.3	49.0	50.3	45.7

Uninoculated control	Wheat straw	3.3	12.7	29.7	33.7	38.7	27.3	12.0
	Sorghum straw	6.3	18.3	38.7	42.7	46.0	40.7	29.7
	Chickpea straw	2.7	16.7	23.3	34.3	43.3	46.0	37.7
	Maize cobs	7.0	21.7	37.0	43.3	47.7	33.0	23.0
	Vegetable waste	5.3	15.3	36.0	46.0	44.7	38.3	37.3
	Saw dust	2.7	6.3	18.7	23.3	36.7	43.0	39.7
				Factors				
A (Consortia)	SE(m)±	0.54	0.75	0.74	0.69	0.78	0.78	0.85
	CD	1.56	2.16	2.14	1.99	2.26	2.25	2.44
B (Substrate)	SE(m)±	0.77	1.06	1.05	0.98	1.11	1.10	1.20
	CD	2.21	3.05	3.03	2.82	3.20	3.18	3.46
A×B	SE(m)±	1.33	1.83	1.82	1.69	1.92	1.91	2.08
	CD	NS	NS	5.25	4.88	5.54	5.51	5.99

(*24 hrs. after inoculation)

Table 4: Actinomycetes population during composting of different substrates

Consortia	**Substrate**	**Actinomycetes population (×10^5 cfu/g of dry matter)**						
		Initial*	**30 days**	**60 days**	**90 days**	**120 days**	**150 days**	**180 days**
Test Consortium	Wheat straw	14.0	17.3	23.0	46.7	62.3	60.0	53.3
	Sorghum straw	13.3	15.3	20.3	41.0	60.7	57.3	48.0
	Chickpea straw	14.7	18.0	32.7	53.7	58.0	63.0	52.3
	Maize cobs	12.3	17.3	24.0	48.7	63.3	63.7	50.7
	Vegetable waste	10.7	13.3	29.3	51.3	66.0	52.7	47.3
	Saw dust	11.0	14.3	20.0	42.3	50.0	54.7	58.0
MPKV Consortium	Wheat straw	1.7	8.0	17.3	24.0	46.0	50.7	38.7
	Sorghum straw	0.7	3.3	8.3	21.7	41.7	49.0	32.7
	Chickpea straw	1.3	7.3	15.7	33.7	47.0	52.0	44.3
	Maize cobs	1.7	5.7	12.7	26.3	47.0	53.0	39.0
	Vegetable waste	0.7	4.3	9.0	31.0	51.0	43.7	27.7
	Saw dust	0.7	3.3	7.7	15.7	30.0	41.3	44.7
Uninoculated control	Wheat straw	1.3	5.3	11.3	20.7	38.0	44.3	36.7
	Sorghum straw	0.7	2.3	7.3	17.7	33.3	37.3	30.0
	Chickpea straw	1.3	6.7	10.3	23.3	40.3	43.3	35.3
	Maize cobs	1.7	4.3	9.3	21.7	41.7	40.7	39.0
	Vegetable waste	0.7	4.0	17.7	34.3	51.0	41.0	28.7
	Saw dust	0.7	2.7	5.3	11.3	26.0	39.3	43.7
				Factors				
A (Consortia)	SE(m)±	0.39	0.47	0.63	0.90	0.88	0.89	0.91
	CD	1.14	1.36	1.82	2.60	2.55	2.57	2.62
B (Substrate)	SE(m)±	0.56	0.67	0.89	1.27	1.25	1.26	1.29
	CD	NS	1.92	2.57	3.67	3.60	3.63	3.70
AxB	SE(m)±	0.98	1.16	1.54	2.21	2.17	2.18	2.23
	CD	NS	NS	4.45	NS	NS	NS	NS

(*24 hrs. after inoculation)

Table 5: Average number of days required for compost maturity, its final C:N ratio, pH and mineral components

Consortia	Substrate	Days for maturity	C:N ratio	pH	Total nitrogen (%)	Total phosphorus (%)	Total potassium (%)
Test Consortium	Wheat straw	156.3	23.62	7.12	0.58	0.12	1.19
	Sorghum straw	90.7	17.08	7.11	0.46	0.23	2.12
	Chickpea straw	86.3	15.46	7.07	1.68	0.34	1.36
	Maize cobs	103.7	20.56	7.14	0.42	1.13	1.63
	Vegetable waste	48.7	13.28	7.03	1.63	0.19	1.30
	Saw dust	179.7	42.52	7.77	0.16	0.42	1.58
MPKV Consortium	Wheat straw	168.7	25.72	7.13	0.56	0.12	1.16
	Sorghum straw	99.0	18.28	7.13	0.43	0.21	2.12
	Chickpea straw	91.7	15.50	7.06	1.58	0.34	1.38
	Maize cobs	115.0	22.70	7.16	0.40	1.07	1.60
	Vegetable waste	53.0	13.45	7.06	1.58	0.19	1.29
	Saw dust	198.3	54.69	7.89	0.14	0.41	1.53
Uninoculated control	Wheat straw	173.0	25.18	7.24	0.48	0.11	1.15
	Sorghum straw	110.0	18.72	6.93	0.41	0.19	2.11
	Chickpea straw	102.7	15.70	7.14	1.53	0.33	1.31
	Maize cobs	135.3	25.61	7.20	0.39	1.06	1.59
	Vegetable waste	59.3	14.42	7.06	1.45	0.18	1.28
	Saw dust	214.3	66.33	8.16	0.13	0.39	1.53
Factors							
A (Consortia)	SE(m)±	0.48	0.25	0.007	0.008	0.007	0.008
	CD	1.37	0.71	0.021	0.022	0.020	0.023
B (Substrate)	SE(m)±	0.67	0.35	0.010	0.011	0.010	0.011
	CD	1.94	1.01	0.029	0.031	0.028	0.032
AxB	SE(m)±	1.17	0.61	0.018	0.018	0.017	0.019
	CD	3.36	1.75	0.051	0.053	NS	NS

Initial C:N ratio: Wheat straw- 75.36, sorghum straw- 43.27, chickpea straw- 40.12, maize cobs- 49.97, vegetable waste- 26.29 and saw dust- 307.17

Initial pH: Wheat straw- 7.83, sorghum straw- 6.90, chickpea straw- 5.85, maize cobs- 6.86, vegetable waste- 6.92 and saw dust- 8.30

respectively. While on the 49th day of sampling population of bacteria was 93×10^6 cfu/g, fungi 22×10^4 cfu/g and actinomycetes was 86×10^5 cfu/g. Similar observations have been reported by earlier workers on microbial population change during composting (Goyal *et al.* 2005; Gazi *et al.* 2007; Devi *et al*. 2012).

Days required for compost maturity

The differences in average number of days required for compost maturity during *in-vitro* composting due to application of different consortia were found statistically significant (Table 5). Test consortium was found significantly superior in reducing the decomposition time of substrates over MPKV consortium and uninoculated control. The reduction in time due to application of test consortium over uninoculated control ranged from 9.65 to 23.36% in different substrates. Vegetable waste decomposed at the fastest rate, while saw dust required highest time. At the final observations it was observed that saw dust compost does not meet the established norms of maturity and stability parameters of compost and hence can be concluded that saw dust did not decompose in the stipulated time.

Gaur (1982) investigated the effect of four mesophilic fungi, *Aspergillus niger, Aspergillus* sp., *Trichoderma*

viride and *Penicillium* sp. on composting of jowar stalk, wheat straw and jamun leaves. Due to inoculation, the period of composting was reduced by one month. Sarkar *et al.* (2011) prepared eleven different consortia of the bacterial strains for degradation of kitchen waste. The maximum reduction in composting time observed was 65% in consortia no. 12 and 55% in consortia no. 7. Reduction in composting period due to inoculation of cellulolytic microorganisms have also been reported by Shinde and Rote (1983), Raut *et al.* (2008) and Iqbal *et al.* (2010).

Changes in pH

The difference in final pH values of compost at maturity were statistically significant (Table 5). The pH of all substrates in experiment shifted towards normal at maturity. Highest pH value at maturity was recorded in the uninoculated saw dust substrate (8.16) while, the least pH value was recorded in uninoculated sorghum straw substrate (6.93). The shift of pH towards normal denotes the maturity and stability of compost.

The present results are in conformity with the results of research workers who revealed from the studies that the composting material gradually decomposes with time and stabilizes and finally the pH stays between 7 and 8 (Ranalli *et al.* 2001; De Oliveira *et al.* 2002; Adebayo *et al.* 2011 ; Himanen and Hanninen, 2011 and Sarker *et al.* 2013).

Changes in C:N ratio

In *in*-vitro experiment lowest C:N ratio at maturity was recorded in the test consortium treated vegetable waste and was par with that treated with MPKV consortium. Highest C:N ratio was recorded in uninoculated saw dust compost (66.34) at final observations confirming that it was not stable and mature for use as fertilizer (Table 5). Among the substrates treated with test consortium, highest C:N ratio was recorded in saw dust while lowest was recorded in vegetable waste. C:N ratio in substrates treated with MPKV consortium ranged from 13.45 to 54.69, while in uninoculated control ranged from 14.42 to 66.34. The treatment with test consortium was found significantly superior in reducing C:N ratio over MPKV consortium and uninoculated control.

Reduction in C:N ratio over initial on decomposition was recorded by several research workers. Goyal *et al.* (2005) observed that the initial C:N ratio of wastes used for composting ranged from 13.9 to 51.1. As the decomposition progressed, C:N ratio reduced and was 11.7 to 28.3. Similar results have also been reported by Limtong *et al.* (1990), Ravankar *et al.* (2000), Mishra *et al.* (2001), Gade *et al.* (2010) and Raj and Antil (2011) who reported that there was a decrease in C :N ratio as the decomposition progressed.

Mineral components of compost at maturity

Minor variations in the mineral content were recorded in the compost at maturity (Table 5). Wheat straw compost recorded numerically higher nitrogen content on application of test consortium and was at par with the MPKV consortium. Highest nitrogen content was also recorded in sorghum straw, chickpea straw, maize straw, vegetable waste and saw dust treated with test consortium. Similarly numerically higher phosphorus and potash content were recorded in the main treatment with newly developed test consortium as compared to the MPKV consortium and uninoculated control.

Patil (1994) prepared compost from wheat straw and found that total N,P,K were in the tune of 0.54, 0.12 and 1.45 per cent, respectively. Verma *et al.* (1999) prepared compost from different organic material like soybean trash and paddy straw and observed that compost had 1.68 per cent of N and 0.43 per cent P. Sarker *et al.* (2013) estimated the nutrient status of compost prepared from sugarcane press mud by microbial consortium. At the end of composting period, the N was found to be 2.34% in press mud compost while phosphorous and potassium content was 1.15% and 1.37. The nutrient content of compost showed the better nutrient levels of concentration compared to control. This is probably because of quick microbial activity leading to decrease in volume of the material. The present results are thus in conformity with the work done by earlier research workers.

Conclusion

It is revealed from the results that the application of cellulolytic microbial consortium on different wastes accelerated the microbial activity, maintained pH and reduced the period of composting, hence can

be concluded that cellulolytic microorganisms can be isolated from naturally decomposing organic sources and used for enhancing composting rate of organic matter. The time required for composting depends upon the characteristics of substrates. Such decomposed organic matter is a good source of mineral nutrients for crop and will reduce the expenditure of farmers on chemical fertilizers.

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