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Effect of municipal solid waste and agricultural composts on growth and yield of Fenugreek seeds (*Trigonella foenum graecum).*

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ABSTRACT

Composting is a natural biological process which is environmentally friendly waste management technology, helpful for quantification of organic matter, leading to recycling of valuable nutrients. The present study deals with the comparison of municipal solid waste and agricultural composts, nutritional quality. The fully degraded solid waste samples were taken and analysed for physico-chemical characteristics and heavy metals concentrations (Cadmium, Copper, Lead, Mercury and Arsenic). The compost maturity tests (germination and plant bioassay) were evaluated using Fenugreek seeds (*Trigonella foenum graecum)*. The results, shows that, more salts and metal ion concentrations are present in MSW compost sample, compared to agricultural compost sample. Heavy metals concentrations are within the permissible limits of Ohai EPA standards in both the compost samples. In the germination and plant bioassay tests, MSW compost samples were found to be more favorable compared to agricultural compost samples. The overall study concluded that, both the samples were safe for use in agricultural fields. Further, municipal solid waste compost has more micronutrients, hence helpful for soil enrichment.

Keywords: Physico-chemical characteristics, Heavy metals, Ohai EPA Standards, Maturity tests, Germination Index (GI).

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INTRODUCTION

Composting is an aerobic exotheric process due to the succession of different microbial communities used in treating biodegradable wastes, for use as a soil conditioner and fertilizer. In addition, it is also the most environmentally friendly and less cost effective and has more capacity to reduce municipal solid waste compared to other known methods, such as incineration, landfill and anaerobic digestion [12, 23]. Cow dung manure is a nitrogen rich matter and is of economic importance as fertilizer, feed supplement or as an energy source. Cow dung manure has been collected and used to supply calcium, magnesium, potassium, nitrogen and phosphorous in the soil, for plant production [31]. Use of compost increases the organic content of soil and can improve its texture, nutrient compounds, water holding and aeration capacities. The application of compost includes: agriculture, horticulture, nurseries, home gardening and other-land reclamation and landfill covers. Compost quality testing (Physico-chemical characteristics and heavy metals concentrations along with compost maturity tests) is necessary to determine the quality of the compost in order to protect the environment and human beings [2]. Results of compost quality testing provide the basis for which recommendations can be made regarding suitable end uses of the product.

The seed germination bioassay could be relatively low sensitive to many toxic substances, because, many chemicals may not be absorbed by seeds and the embryonic plant draws its nutritional requirements internally from seed stored materials and is effectively isolated from the environment. At the same time, the roots are responsible for absorption and accumulation of metals, so the root lengths are more affected by the concentration of the compost [3,17,21].

Fenugreek seed was commonly used as a condiment in food preparation for its nutritive and restorative properties. The seed has been used in folk medicine for centuries for a wide range of diseases, including diabetes [10]. Fenugreek is a very useful legume crop and can be incorporated into short-term rotation [20], for hay and silage (livestock feed), and for soil fixation of nitrogen [24]. Like many other leguminous crops, the production of this crop is affected by environmental stress, such as: drought and salinity [1].

In the present research paper, comparative study on nutritional status of the municipal and agricultural compost samples was done, using various tests like physico-chemical characteristics, heavy metals concentrations, compost maturity test (germination and plant bioassay) using Fenugreek seeds.

MATERIALS AND METHODS

Collection of compost samples:

Two types of mature composts were tested: municipal solid waste (MSW) from the windrow composting plant set up at Vidyaranyapuram, Mysore and the other agricultural compost sample, collected from Hosur, K.R. Nagar Taluk, Mysore District. These compost samples were taken randomly within a 0.5 meter quadrat and mixed into a composite sample representative of that particular sample. The segregation of stones, plastic, *etc*., were carried out manually. Further, the samples were dried using laboratory oven at 70^0C or sunlight and powdered, passed through 2 mm mesh sieve to obtain a uniform powder. Later, analysis was carried for various characteristics such as physico-chemical, heavy metals, germination and plant bioassy tests. The analysis was carried out as per standard methodology [16,18,25,28-30]. All the experiments were carried out in triplicates and the average value was presented.

Method of analysis of physico-chemical characteristics and heavy metals concentrations:

Measure the temperature using a HERMES Brand Mercury thermometer [27]. Moisture content (drying at 1050 C to constant weight by gravimetric method; [8]); Particle and Bulk densities (Pycnometric method; Saha Arun Kumar 2008); pH (1:5 water extract by pH meter; [8, 27]); Electrical Conductance (1:5 water extract, digital conductivity meter; [8]); Total water soluble solids (1:5 water extract, gravimetric method; [8]); Calcium and Magnesium (1N ammonium acetate extract, EDTA method; [14]); Chlorides (1:5 water extract, AgNO3 method; [18]); Calcium carbonate (1N HCl extract, titration method; [8]); Total organic carbon (cold oxidation with potassium dichromate, [33]); Organic matter content was calculated from determined organic carbon using conversion factor 1.724 [26], Total organic nitrogen (Kjeldhal method; Mani,

et.al., 2007), Nitrate nitrogen (1N of $CuSO_4$ and 0.6% $AgSO_4$ extract, Brucine sulphate method; [13]), Ammonia nitrogen (1:5 sodium acetate extract, Nessler's reagent method;[32]); Soluble sulphate (1:5 water extract, $BaCl_2$ method, [8]); Phosphorus (tri acid mixture with a aqua digestion, 18); Potassium and Sodium (1N ammonium acetate extract using flame photometer method, [18]), Soluble sulphates (1:5 water extract; [8]). The C/N ratio of the compost was determined from the ratio of total organic carbon to total nitrogen [19]. The water soluble and acid digested extracts were analyzed for quantitative estimation of heavy metals (Copper, Cadmium, Lead, Mercury and Arsenic) using Atomic Absorption Spectrophotometer [18, 28, 29].

Methods of Stability test

Jar test (Odour development)

500 gm of compost sample was added to enough water to make the compost sample moist. The sample was placed in a sealed plastic bag and kept for a week at room temperature [31]**.**

Self-heating test (Heat production)

A gallon-size container was filled with compost having 40 to 50% moisture content, the container was sealed and insulated with insulating material **[31].** Record the temperature of the compost sample.

Method of maturity tests

$$GI = \frac{\%\ G\ X\ \%\ L}{10{,}000}$$

Methods of germination bioassay test

During the test, about 10 g of powdered and dried (room temperature condition around 25^0C for 24 hours) composts sample was taken in a beaker. 50 ml distilled water was added and stirred the contents for one hour (1:5 ratio, 1 part sample and 5 parts distilled water) and allowed to settle approximately for 20 minutes. The contents were centrifuged to obtain aqueous extracts, further they were filtered through a double layered muslin cloth and the extracts were called as 100% full strength. At the same time 10 times dilution samples were done using 1 ml of 100% full strength sample with 10 ml of distilled water. Both these samples were used as germination media. 8 Fenugreek (*Trigonella foenum graecum)* seeds were placed on a Whatman filter paper (Number 42) which is placed inside a Petri dish, wetted with 1 ml of each germination solution. Distilled water was used as a control and five replicates were kept for each treatment. The Petri dishes were placed in a sealed plastic bag to minimize water loss while allowing air penetration and were then kept in the dark for 24 hours at a steady warm temperature of 27^0C. After the incubation period, number of germinated seeds and the primary radical lengths were measured and expressed as a percentage of the control (germination index). Data were analyzed statistically against compost age and concentration of organic carbon in the growing media. The germination index (GI) was calculated using the following equation [34].

Where**, %G:** Percentage of germination, **%L:** Percentage of radical length

Method of plant bioassay tests

The experiments can be performed outdoors using plot method. The experiment designed to include use of municipal solid waste, agricultural compost and soil samples, as shown in Table 1, which was carried out for 70 days. Initially, the Fenugreek seeds were planted in the specific location of the plot and watered regularly (20 Fenugreek seeds were used in each of the steps)(Table 1 and Figure 2). The plots were properly maintained to minimize the variations in temperature, light and other environmental factors. Data was recorded in the 7^{th} week, the growth pattern of the seeds and the health indicators, like color, diseases, *etc*.

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Table 1: The different compost samples with soil combination of plant bioassay tests

Name of the sampling	Composition	Remarks
Control	100% Soil (20 Fenugreek seeds were used)	After 7th week in each treatment, the 10 plants were picked and analysed for the tests like root, shoot, total length, no. of leaves, no. of flowers and no. of pods of the plant. At the same time, fresh and dry weight of the plant root, shoot and leaves, pods weight were calculated (mean values).
MSW compost sample (Final stage)	25% of MSW compost sample +75% Soil (20 Fenugreek seeds were used)	
Agricultural compost sample (Final stage)	25% of Agricultural compost sample + 75% soil (20 Fenugreek seeds were used).	

A) B)

Figure 2: Plant bioassay plots A) Initial plant growth in MSW and Agricultural compost sample B) Final plant growth in MSW compost

RESULTS AND DISCUSSIONS

The physico-chemical characteristics such as moisture content (40%), total water soluble solids (22.8 mg/g), bulk density (0.81 mg/m^3), total organic carbon (9.8%), organic matter (16.98%), calcium carbonates (18%), carbonates (0.18 me/L), bicarbonates (2.51 me/L), ammonia nitrogen (0.002%), nitrate-nitrogen (1.9%), Total Phosphorus (1.8%), TKN (1%) and C/N ratio (9.8%) were more for agricultural compost samples compared to municipal compost sample.

At the same time, the pH (9.8), Electrical conductance (6.9 dS/m), Particle density (2.2 mg/m^3), Water holding capacity (62.5%), Chlorides (0.11%), Calcium (0.29%), Magnesium (0.038%), Soluble sulphates (66.2%), Sodium (0.078%), Potassium (0.16%) and heavy metals concentrations were more for municipal solid waste compost samples compared to agricultural compost sample (Table 3). According to researcher [13], high percentage of nitrogen rich yard trimming feedstock materials shows the high pH.

In the present investigation, the particle density was more in municipal solid waste compost sample compared agricultural compost sample. This may be due to the large amount of heavy minerals such as magnetite, limonite, hematite, *etc.* present in the compost sample and, usually, mineral composts varies from 2.65 to 2.75 mg/m^3[25]. The electrical conductance was more in municipal solid waste compost sample which may be due to the degradation of organic matter to release cations [7]. The excess of soluble solids may be due to zero-oxidation state of organic matter from the domestic waste and dairy product wastes.

This study concludes that, more salt and metal ion concentrations are present in MSW compost sample compared to agricultural compost sample, which may be due to the feedstock which contains various metals in different forms of MSW compost sample.

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The Physico-chemical characteristics and heavy metals concentrations in the final stages of MSW and agricultural compost were compared with recommended standards. The results obtained reveal that, all the characteristics are within permissible limits of recommended standards [Except, pH (both the compost samples), Electrical conductance for MSW with 6.9 dS/m which are above the permissible limits]. This study also confirms that, both the samples were safe for use in agricultural fields. Further, MSW composts has more micronutrients, hence, helpful to soil enrichment, similar observations were reported from [22]. The stability tests on MSW and agricultural compost samples are within the permissible limits of EU standards (Table 2).

Table 2: Stability test for different compost samples

Sample type	Jar test	Color	Self-heating test
			Heat production (^{0}C)
MSW compost	Earthy Smell	Dark chocolate brown	30
Agricultural compost	Earthy Smell	Dark brown	31

Table 3: Comparative studies on Physico-chemical characteristics at final stages of MSW and agricultural compost samples

SL. No.	Characteristics	Units	MSW compost	Agricultural Compost	Recommended standards
1.	Moisture content	%	38	40	45[1]
2.	pH	-	9.8	9.2	6.5-8.5[3]
3.	Electrical conductance	dS/m	6.9	3.9	2-6[4]
4.	Bulk density	mg/m^3	0.748	0.810	0.12- 0.369[5]
5.	Particle density	mg/m^3	2.2	1.5	0.25[2]
6.	Water holding capacity	%	62.51	53.06	NA
7.	Total water soluble solids	mg/g	18	22.8	NA
8.	Chlorides	%	0.11	0.084	NA
9.	Total organic carbon	%	5.94	9.8	NA
10.	Organic matter	%	10.24	16.98	>30 [10]
11.	Calcium	%	0.29	0.27	1.0-4.0 [12]
12.	Magnesium	%	0.038	0.012	0.2-0.4 [13]
13.	Soluble sulphates	%	66.2	4.6	NA
14.	Calcium carbonate	%	7.75	18	NA
15.	Carbonates	me/L	0.12	0.18	NA
16.	Bicarbonates	me/L	2.01	2.51	NA
17.	Ammonia-nitrogen	%	0.001	0.002	0.05[5]
18.	Nitrate -nitrogen	%	1.2	1.9	2-4[6]
19.	Total Phosphorus	%	0.97	1.8	0.4-1.1[7]
20.	TKN	%	0.8	1.0	1.0-3.0[14]
21.	C/N ratio	-	7.42	9.8	<25[11]
22.	Sodium	%	0.078	0.019	NA
23.	Potassium	%	0.18	0.16	0.6-1.7[8]
24.	Copper	mg/kg	400	39	1500[15]
25.	Cadmium	mg/kg	1.5	BDL	35[15]
26.	Lead	mg/kg	2	BDL	300[15]
27	Mercury	mg/kg	5	BDL	7.8[15]
28	Arsenic	mg/kg	2	BDL	41[15]

Note: NA- Not available' [1]Recommended range of moisture content, Biotreat, 2003, [2, 3, 4, 5, 6, 7, 8 & 9]Recommended particle density, pH, conductance, bulk density, available ammonia nitrogen, nitrate nitrogen, total phosphorus and potassium of compost, Bord na Mona, 2003, [10 & 11]Limit for organic matter and C/N ratio specified by the Environmental Protection Agency in accordance with Waste Licensing under the Waste Management Act 1996, [12, 13 & 14]Recommended range of calcium, magnesium and total nitrogen in compost (Barker, 1997) & [15]Ohai EPA Standards.

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Table 4: Comparative studies on germination bioassay for MSW and agricultural compost samples

Tests	Sampling methods	Soil	MSW compost	Agricultural compost
Mean germination (Gt) (mm)	100% Full Strength	8	8	8
	10times dilution			
Mean radical length (Lt) (mm)	100% Full Strength	27.8	26	24
	10times dilution		27	26
% G	100% Full Strength	80	100	100
	10times dilution		100	100
% L	100% Full Strength	100	93.6	86.3
	10times dilution		97.1	93.5
Germination Index (%)	100% Full Strength	0.8	**0.93**	**0.863**
	10times dilution		**0.97**	**0.935**

Maturity test for germination bioassay test

Fenugreek seeds mean germination values had no significant difference between the MSW and agricultural compost samples. The Soil alone was taken as a control for this study along with an MSW and agricultural compost (Table 4 and Figure 1).

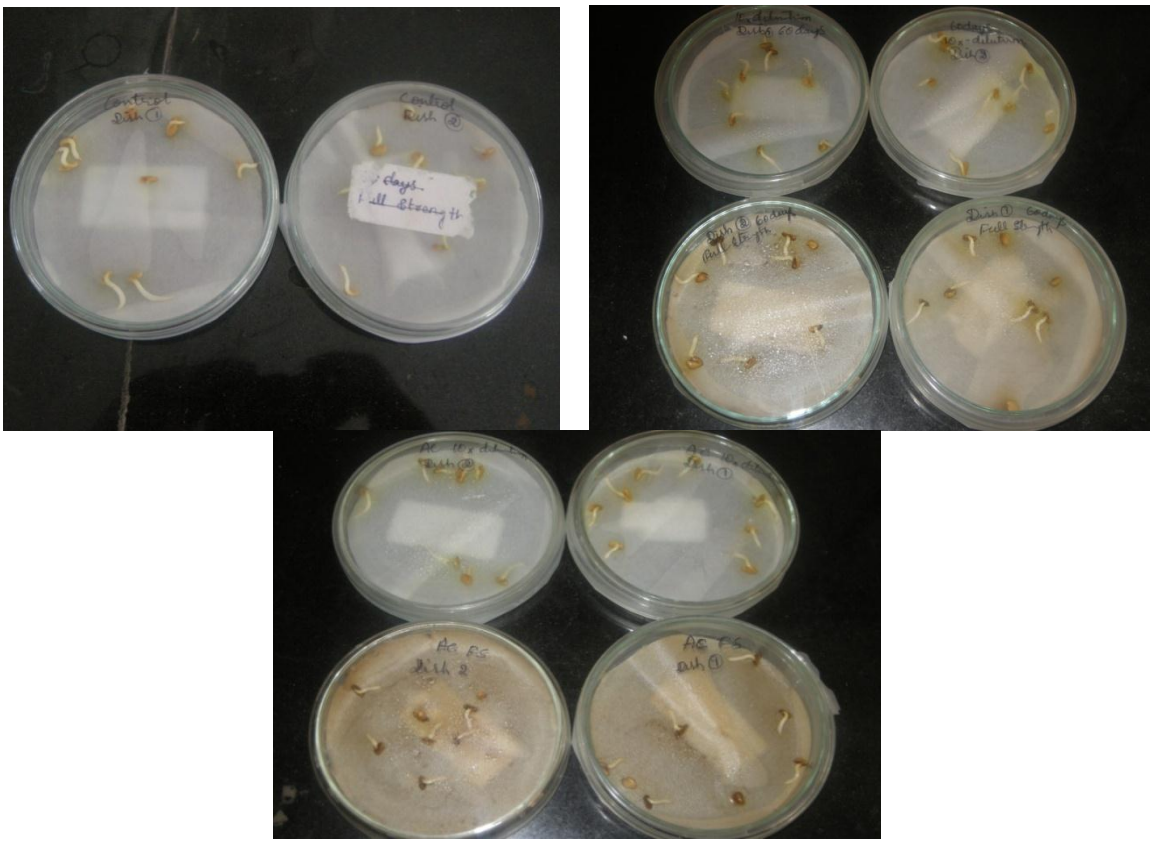

Figure 1: Seed germination test results for control, MSW and agricultural compost sample

The germination index values recorded were more in municipal solid waste compost sample compared to agricultural compost sample. The values of the germination index for MSW compost sample, 0.93% (Full Strength) and 0.97% (10times dilution) and for agricultural compost sample, 0.863% (Full Strength) and 0.93% (10times dilution).

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The maturity test for plant bioassay

The results obtained from the study reveals that height of plant parts root (16.69 cm), shoot (38.01 cm) and total height of the plant (54.68 cm), number of leaves (13.4), number of flowers (1.3) and number of seed pods (1.1) were in MSW compost sample compared to agricultural compost samples.

Table 5: Comparative studies on plant bioassay (plant height) using MSW and agricultural compost

	Root length (cm)	Shoot length (cm)	Total length (cm)	No. of Leaves	No. of Flowers	No. of Seed pods
Soil	10.4	22.4	32.9	10.2	0.5	0.8
MSW compost	**16.69**	**38.015**	**54.68**	**13.4**	**1.3**	**1.1**
Agricultural compost	15.1	26.55	41.65	10.47	0.75	1

Table 6: Comparative studies on plant bioassay (plant weight) at the final stages of MSW and agricultural compost

	Root weight (g)		Shoot weight (g)		Leaves weight (g)		Seed pods (g)		Total (g)	
	FW	DW	FW	DW	FW	DW	FW	DW	FW	DW
Soil	0.342	0.136	2.15	0.59	3.4	0.49	2.08	0.4	7.98	1.62
MSW compost	**0.765**	**0.18**	**5.85**	**1.097**	**7.466**	**0.885**	**2.063**	**0.35**	**16.14**	**2.61**
Agricultural compost	0.797	0.229	3.249	0.778	4.37	0.599	2.858	0.49	11.28	2.1

Note: FW: Fresh weight in (g), **DW**: Dry weight (g)

The fresh and dry weight of the plant roots (0.765 and 0.18 g), shoots (5.85 and 1.097 g), leaves (7.466 and 0.885 g), seeds, pods (2.06 and 0.35 g) and total weight of the plants (16.14 and 2.61 g) recorded were more in MSW compost sample compared to agricultural compost sample compared to control (100% soil). The study also confirms that, MSW composts sample contains both organic compounds and metals (sodium, potassium, calcium, magnesium) and greatly influenced the plant growth (Table 6 and Figure 3, 4 & 5).

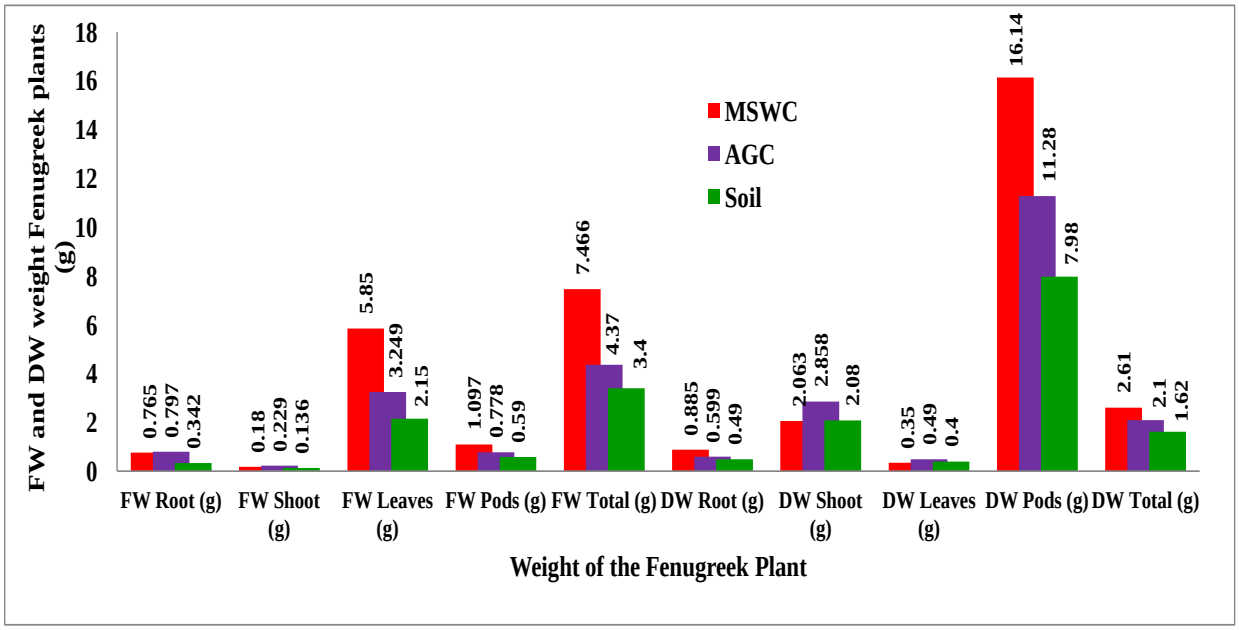

Figure 3: Fenugreek plant weight in MSW and agricultural compost

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A) B) C)

Figure 4: Plant bioassy test at 4th week A) Control B) MSW compost C) Agricultural Compost

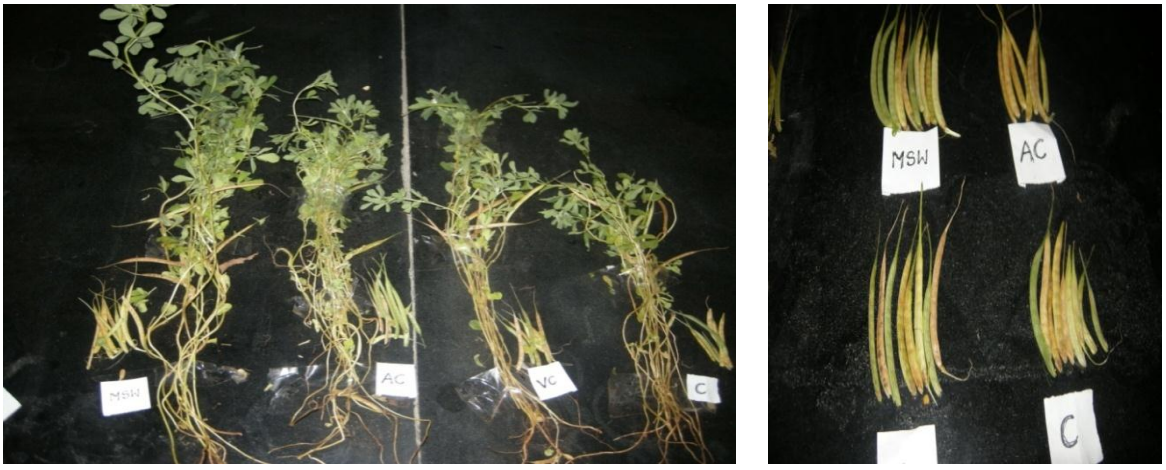

Figure 5: Plant bioassy test for 7th week Plant height and pod size of MSW, Agricultural composts and Control

CONCLUSIONS

The above findings, show that, the stability tests on MSW and agricultural compost samples are within the permissible limits of EU standards. Physico-chemical characteristics are within permissible limits of recommended standards [Except, pH (both the compost samples), Electrical conductance for MSW with 6.9 dS/m, above the permissible limits].

Comparing the tow compost samples, the physico-chemical characteristics, heavy metals concentrations, germination and plant bioassay were more for municipal solid waste compost sample compared to agricultural compost sample. Exspecially, most inorganic salts and metal ion concentrations present in MSW compost sample. The overall study shows that, the compost produced by municipal solid waste has high nutrient values which can be used effectively as bio compost or soil amended and this compost also can reduce the application of organic fertilizer.

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