Int.J.Curr.Microbiol.App.Sci (2018) *7*(10): 1386-1395

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 10 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.710.154

Residual Effect of Enzyme Industrial Waste-Municipal Solid Waste Composts Application on Growth, Yield, Content and Uptake of Nutrients by Cowpea

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Keywords

Compost, Cowpea, industrial wastes, Municipal solid waste, Residual effect

Article Info

Accepted:
12 September 2018
Available Online:
10 October 2018

A B S T R A C T

A field experiment with cowpea was conducted in a sandy loam soil, in the Eastern Dry Zone (Zone 5) of Karnataka to evaluate the residual effect of enzyme industrial waste-municipal solid waste composts on growth, yield and nutrient uptake of cowpea during 2014 following a maize crop. The results revealed that the plant height (80.93 cm), number of branches (8.18), yields of cowpea (765.67 kg ha^{-1}) and biomass (1806.97 kg ha^{-1}) were higher in treatment T_9 (50 % N through PS + 50 % N through FYM) indicating the residual effect. The application of enzyme industrial waste-municipal solid waste composts viz. T_6 (MEES compost @ 10 t ha^{-1}) and T_7 (PS compost @ 10 t ha^{-1}) recorded similar plant height, number of branches and cowpea yields of 526.50 and 654.33 kg ha^{-1} and haulm yields of 1289.93 and 1570.40 kg ha^{-1} respectively. Application of 100%NPK +FYM @ 5 t ha^{-1} resulted in lesser growth, yield, nutrient concentration and uptake by cowpea. Application of enzyme industrial waste- municipal solid waste composts resulted in similar concentration of nutrients in cowpea, haulm and their uptake indicating an on par performance revealing their suitability as organic nutrient source for use in agriculture.

Introduction

Compost addition to soil may enhance crop growth due to an improvement in the physical, chemical and biological properties of soil. Composts prepared using different raw materials could increase crop growth and nutrient uptake. Variety of organic wastes could be used as organic manure as such or after composting. However the information on the utilization of enzyme industrial wastes in preparation of composts and their field evaluation is scarce.

Application of composts or manures to soil will lead to a residual effect in terms of crop production as well as by the influence on soil properties (Eghball *et al.*, 2004). Application of compost and farm yard manure had residual effects when applied at 16 tonnes per acre and farm yard manure exhibited the largest residual effect. The residual effect of town refuse compost was 72 per cent of the residual effect of farm yard manure (Garner, 1966). Residual effect of application of composts could be understood by an increased nutrient level in the test crop in the following years or seasons. Application of dairy cattle manure exhibited residual effect on millet and rye forage and this was evident from an increase in the levels of K and Mg in millet and K and Ca in rye (Mugwira, 1978). Phosphocompost and sulphocompost were approximately 12 and 60 per cent as effective as urea during first season's winter cabbage and both composts were equally effective as urea during the second season's maize crop (Mahimairaja *et al.,* 1995). The N content in forage and P uptake by corn were found to be higher in the organically amended plots in the second cut in the second year on application of sewage sludge and sludge compost (Warman and Termeer, 2005).

Here, this field experiment was conducted with the objective to evaluate enzyme industrial waste-municipal solid waste composts to understand its residual impact on growth, yield, concentration and uptake of nutrients by cowpea.

Materials and Methods

A field experiment with cowpea was conducted in a sandy loam soil, geopositioned at 13º27″ N latitude and 77º14″ E longitude near Nelamangala, Bangalore district in the Eastern Dry Zone (Zone 5) of Karnataka to evaluate the residual effect of enzyme industrial waste-municipal solid waste composts on growth, yield and nutrient uptake of cowpea. Two enzyme industrial waste-municipal solid waste composts and fertilizers were used to know the effects on agronomic characteristics, growth, yield and nutrient uptake by cowpea plants.

Experimental details

Two composts namely, MEES compost (multiple effect evaporator salts + municipal solid waste) and primary sludge (PS) compost (Primary sludge + municipal solid waste) prepared by mixing of enzyme industrial wastes and municipal solid wastes were used in this study. These composts were evaluated for their residual effects on growth, yield and nutrient uptake in cowpea which was grown as the residual crop following the main crop which was maize. The field experiment was laid out in Randomised Complete Block Design consisting of 9 treatments in three replications.

The treatment details for the first crop were T_1: Package of Practices (100 % NPK + FYM @ 10 t ha^{-1}), T_2: 100 % NPK + FYM @ 5 t ha^{-1}, T_3: 50% N through MEES compost + 50 % N through urea + P and K, without FYM, T_4: 50% N through PS compost + 50 % N through urea + P and K, without FYM, T_5: FYM @ 10 t ha^{-1}, T_6:MEES compost @ 10 t ha^{-1}, T_7:PS compost @ 10 t ha^{-1}, T_8: 50% N through MEES + 50 % N through FYM, T_9: 50% N through PS + 50 % N through FYM.

The application rates of MEES compost and PS compost were calculated by taking into account the N recommendation to the initial crop (maize). The content of major nutrients in MEES compost was 2.28, 0.46 and 1.94 and PS compost was 1.93, 3.29 and 0.81 per cent N, P and K respectively. Both the composts followed similar trend in micronutrients concentration: Fe>Mn>Zn>Cu. The nitrogen needs were met from the compost as well as the nitrogenous fertilizers applied. This experiment was carried out in the same field without disturbing the lay out using cowpea as the test crop. Cowpea (var. AV 5) was raised on residual nutrients left over in soil after harvest of maize for 107 days duration from Nov.2013 to first week of March 2014. During this experiment, fertilizer or manure was not added. The growth of cowpea was determined at 30 days after sowing (DAS), 60 DAS and at harvest. After harvest the haulm as well as cowpea yields were measured. Following the standard procedures, nutrient concentration and nutrient uptake by the crop were determined.

Statistical analysis

Fisher's method was adopted for analysis of variances and interpretation of the data. The level of significance used in 't' test was P=0.05 (Panse and Sukhathme, 1967).

Results and Discussion

Growth and yield of cowpea

Residual effect on application of composts and industrial wastes on the growth parameters of cowpea recorded significant increase in plant height and number of branches at 60 days after sowing and at harvest (Table 1).The plant height (80.93 cm) and number of branches (8.18), yields of cowpea (765.67 kg ha^{-1}) and biomass (1806.97 kg ha^{-1}) were higher in treatment T_9 (50 % N through PS + 50 % N through FYM).The treatments T_6 (MEES compost @ 10 t ha^{-1}) and T_7 (PS compost @ 10 t ha^{-1}) recorded similar plant height, number of branches and cowpea yields of 526.50 and 654.33 kg ha^{-1} and haulm yields of 1289.93 and 1570.40 kg ha^{-1} respectively and these did not differ significantly to each other. The increase in biomass and growth on application of composts may be attributed to the positive residual effect of the same on the physical, chemical and biological properties of soils. This has resulted from the increased availability of nutrients as a result of mineralization of organic matter manifesting the release of nutrients like nitrogen and phosphorus thus explaining the positive residual effect of composts on plant growth. The results may be due to favourable influence of nitrogen on higher absorption of nutrients from the rhizosphere and supply to crop resulting in higher dry matter production. These results are in conformity with that of Bevacqua (1994), Soumare *et al.*, (2003a) who reported higher growth and yields on application of composts.

Nutrients content in cowpea and haulm

The concentration of nitrogen in cowpea was significantly influenced due to the residual effect of enzyme industrial waste-municipal solid waste composts whereas P and K contents were not significantly different between the treatments (Table 2). Higher concentrations of N (4.28%), P (0.42%) and K (1.09%) were recorded in treatment T_9 (50 % N through PS + 50% N through FYM).The major nutrients concentration remained on par with each other in case of application of composts (T_6: MEES compost @ 10 t ha^{-1} and T_7: PS compost @ 10 t ha^{-1}) recorded 3.11 and 3.29 per cent N, 0.35 and 0.40 per cent P and 1.06 and 1.09 per cent K respectively.

This increase in the content of major nutrients (N, P and K) on addition of compost and organic sources is due to the increased mineralization and subsequent release of N, P and K from organic amendments and the larger quantities of P and K supplied by the organic sources (Terman *et al.,* 1973). Subsequently after the application, there will be less mineralization of nutrients *viz.* only a fraction of total N (deHaan, 1981) and less P (Iglesias-Jimenez *et al.*, 1993) will be available to plants immediately after application. The increase in P content after few months of application is attributed to the increased mineralization of P leading to the increased utilization of native P. An enhanced availability of P added through industrial solid waste composts has been made available by the dissolution of P by organic acids produced during the decomposition of organic matter.

The concentration of S and micronutrients varied significantly between the treatments. Higher contents of Ca (0.81%), Mg (0.44 %) and S (0.34%) and micronutrients (Fe, Mn, Zn and Cu: 93.87, 46.27, 27.40 and 15.27 mg kg^{-1} respectively) were recorded in T_9: 50 % N through PS + 50% N through FYM. Addition of composts significantly increased the calcium and magnesium content in plants (King *et al.,* 1974); manure residuals increased the levels of K and Ca in rye and K and Mg in millet (Mugwira, 1978); increased S and Mn in blueberry leaves in an acidic sandy loam (Warman *et al.,* 2004); increased Mn in Spinach in calcareous soils (Maftoun *et al.,* 2004), increased Zn concentration in different plant species (Nogales *et al.,* 1985); in corn (Terman *et al.,* 1973). The slow mineralization of composts on their application has resulted in an increased concentration of nutrients in the residual crop.

In cowpea haulm, nutrients content except Mg varied significantly between treatments. Higher concentration of nitrogen (1.73 %), P (0.30%) and K (2.0%) was observed in the treatment T_9 (50 % N through PS + 50% N through FYM). The application of composts (T_6: MEES compost @ 10 t ha^{-1} and T_7: PS compost @ 10 t ha^{-1}) recorded similar contents of nutrients. Larger application rates of compost have resulted in addition of excess of P and other nutrients to soil. The compost produced a greater effect on plant P because of the high total P application which was used to provide equivalent rates of N. An availability of 16-21 per cent of total N as NH_4NO_3 in soil six months after application of MSW compost (Iglesias-Jimenez and Alvarez, 1993); an increase in N in the forage amended with compost was observed in the second cut in the second year (Warman and Termeer, 2005); a better second season crop (Mahimairaja *et al.,* 1995) where composts were found equally effective as urea during the second season crop indicating the improved residual value of the compost. Addition of compost resulted in the extraction of 50 times more K by millet crop when compared to control (Hortenstine and Rothwell, 1969); provided a relatively high amount of K which caused a steady increase in plant K (Warman and Termeer, 2005), significantly higher K concentrations in plants (Soumare *et al.,* 2003b).

In the case of secondary and micronutrients too, the concentration in haulm recorded similar trend. Treatment T_9: 50 % N through PS + 50 % N through FYM recorded higher concentration of secondary nutrients (1.34, 0.60 and 0.34 per cent Ca, Mg and S respectively) and micronutrients in haulm.

The treatments T_6 (MEES compost @ 10 t ha^{-1}) and T_7 (PS compost @ 10 t ha^{-1}) recorded similar nutrient contents. Increased blueberry leaf S concentration was observed when MSW compost was applied to an acidic sandy loam (Warman *et al.,* 2004); increased foliar iron content was observed in trees grown in composted biosolid plots, although this was not a significant increase over unamended control plots(Lombard *et al.,* 2011). Application of composts resulted in an increase in Zn content in vegetables (Wong *et al.,* 1983) and an increase in the Cu content in corn plants (Roghanian *et al.,* 2012).

The concentration of heavy metals (Cd, Ni, Pb and Cr) was below the detectable limits in cowpea and haulm. The concentration of nutrients was relatively higher with the application of primary sludge and farm yard manure on N basis (T_9: 50 % N through PS + 50% N through FYM). This was significantly higher in the case of N, S and micronutrients in cowpea and in all the nutrients except Mg in the case of cowpea haulm. The increase in content of nutrients in haulm is attributed to the increased availability of nutrients due to increased mineralization of nutrients from the applied organic manures. The concentration of nutrients was higher in the following crops than the first crop in organic manure treatments resulting from an increased mineralization.

Table.1 Residual effect of enzyme industrial waste-municipal solid waste composts on growth parameters and yield of cowpea

Treatments	Plant height (cm)			No. of branches			Cowpea Yield	Haulm Yield
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	kg ha^{-1}	
T_1	11.67	36.32	71.00	2.32	6.31	7.19	449.83	1057.11
T_2	10.94	30.50	65.70	2.07	4.74	5.50	382.83	926.46
T_3	11.10	32.32	68.30	2.17	5.19	5.97	388.50	928.52
T_4	11.55	34.71	70.10	2.22	6.07	6.89	404.33	974.44
T_5	11.84	37.91	71.60	2.32	6.54	7.46	467.08	1102.32
T_6	12.85	45.65	76.13	2.40	6.93	7.77	526.50	1289.93
T_7	13.35	46.76	78.60	2.40	7.06	7.92	654.33	1570.40
T_8	12.68	40.56	75.37	2.33	6.63	7.47	478.67	1134.44
T_9	17.01	48.17	80.93	2.41	7.27	8.18	765.67	1806.97
Sem±	1.24	3.18	2.91	0.10	0.44	0.47	51.20	123.82
C.D. at 5%	NS	9.54	8.74	NS	1.31	1.41	153.52	371.24

T_1: POP (100 % NPK + FYM @10t ha^{-1})
T_2: 100 % NPK+ FYM @ 5 t ha^{-1}
T_3: 50% N through MEES compost + 50 % N through urea, PK without FYM
T_4: 50% N through PS compost+ 50 % N through urea, PK without FYM
T_5: FYM @ 10 t ha^{-1}
T_6: MEES compost @ 10 t ha^{-1}
T_7: PS compost @ 10 t ha^{-1}
T_8: 50 % N through MEES + 50 % N through FYM
T_9: 50 % N through PS + 50 % N through FYM

Table.2 Residual effect of enzyme industrial waste-municipal solid waste composts on nutrients content in cowpea and haulm

	Cowpea									
Treatments	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**Zn**	**Cu**
	%						**mg kg^{-1}**			
T_1	2.19	0.30	1.01	0.56	0.41	0.28	66.67	40.73	20.80	8.17
T_2	1.48	0.25	0.96	0.49	0.34	0.21	41.73	33.40	14.07	5.37
T_3	1.49	0.27	0.98	0.53	0.37	0.22	48.33	36.27	15.00	6.17
T_4	2.57	0.29	0.98	0.55	0.37	0.27	61.27	39.80	15.80	7.83
T_5	2.72	0.30	1.03	0.59	0.41	0.31	73.13	42.13	21.67	9.13
T_6	3.11	0.35	1.06	0.62	0.43	0.33	81.53	44.07	23.27	12.36
T_7	3.29	0.40	1.09	0.62	0.53	0.33	87.40	44.87	26.47	12.47
T_8	2.96	0.32	1.03	0.60	0.42	0.31	81.07	42.87	22.53	11.00
T_9	4.28	0.42	1.09	0.81	0.44	0.34	93.87	46.27	27.40	15.27
Sem±	0.46	0.04	0.04	0.13	0.07	0.03	1.90	0.51	0.46	0.29
C.D. at 5%	1.37	NS	NS	NS	NS	0.08	5.70	1.54	1.39	0.86
	Haulm									
T_1	1.05	0.19	1.79	1.16	0.41	0.23	43.51	39.45	18.20	5.68
T_2	0.74	0.06	1.41	0.79	0.33	0.18	36.90	34.47	9.72	4.50
T_3	0.82	0.12	1.67	0.95	0.37	0.21	37.12	34.80	13.58	4.78
T_4	0.94	0.15	1.73	1.08	0.40	0.21	38.61	36.78	17.53	5.55
T_5	1.14	0.20	1.82	1.17	0.42	0.23	47.01	42.35	19.35	5.93
T_6	1.34	0.22	1.86	1.25	0.52	0.24	83.31	48.99	20.27	6.29
T_7	1.52	0.28	1.91	1.34	0.54	0.29	88.62	49.10	20.69	6.40
T_8	1.30	0.21	1.84	1.21	0.48	0.23	62.66	44.55	19.85	6.13
T_9	1.73	0.30	2.00	1.34	0.60	0.34	113.01	51.66	22.65	7.13
Sem±	0.21	0.05	0.10	0.18	0.08	0.02	3.22	0.69	0.28	0.10
C.D. at 5%	0.62	0.14	0.29	0.54	NS	0.06	9.70	2.06	0.83	0.31

Table.3 Residual effect of enzyme industrial waste-municipal solid waste composts on nutrients uptake by cowpea and haulm

	Cowpea									
Treatments	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Mn**	**Zn**	**Cu**
	kg ha^{-1}						**g ha^{-1}**			
T_1	9.86	1.36	4.52	2.49	1.86	1.26	29.98	18.32	9.36	3.68
T_2	3.66	0.99	3.68	1.88	1.45	0.91	15.81	12.68	5.28	2.06
T_3	5.96	1.14	3.92	2.09	1.54	0.93	18.83	13.98	5.92	2.40
T_4	10.55	1.15	3.99	2.27	1.53	1.09	24.84	16.13	6.46	3.15
T_5	12.64	1.43	4.84	2.77	1.89	1.46	34.16	19.68	10.13	4.25
T_6	17.03	1.85	5.60	3.06	2.31	1.78	43.30	23.10	12.33	6.58
T_7	21.48	2.58	7.15	4.11	3.44	2.19	57.16	29.35	17.29	8.15
T_8	14.74	1.49	4.93	2.97	2.05	1.45	38.84	20.54	10.80	5.23
T_9	32.79	3.20	8.32	6.22	3.34	2.60	71.96	35.43	20.98	11.70
Sem±	2.67	0.26	0.59	1.00	0.44	0.22	3.91	2.02	1.07	0.50
C.D. at 5%	8.00	0.79	1.76	NS	1.32	0.65	11.71	6.06	3.21	1.50
	Haulm									
T_1	11.05	2.03	18.98	12.29	4.32	2.39	46.00	41.71	19.24	6.01
T_2	5.78	0.53	13.36	7.25	2.88	1.68	34.31	31.80	8.97	4.11
T_3	7.38	1.43	15.41	9.10	3.30	1.92	34.74	32.60	12.48	4.48
T_4	9.17	1.45	16.90	10.90	3.93	2.08	37.59	35.71	17.03	5.42
T_5	12.97	2.25	20.09	12.77	4.60	2.51	51.66	46.61	21.38	6.55
T_6	17.14	2.99	24.25	16.74	6.47	2.93	107.05	63.28	26.25	8.11
T_7	23.96	4.38	30.14	21.37	8.23	4.48	139.84	77.16	32.42	10.05
T_8	14.72	2.46	21.10	13.66	5.27	2.59	71.29	50.61	22.47	6.97
T_9	31.42	5.38	36.21	24.23	10.80	6.19	204.51	93.39	40.94	12.88
Sem±	3.26	0.62	2.70	3.30	1.04	0.43	10.10	5.38	2.21	0.72
C.D. at 5%	9.79	1.87	8.08	9.88	3.11	1.29	30.27	16.14	6.62	2.16

Nutrient uptake by cowpea and haulm

Nutrient uptake by cowpea varied significantly with treatments except in the case of Ca. Higher uptake of N, P and K (32.79, 3.20 and 8.32 kg ha^{-1}) by cowpea was recorded in treatment T_9 (50 % N through PS + 50% N through FYM) (Table 3). Repeated application of composts resulted in higher N content and uptake in Spinach and lettuce (Kropisz and Russell 1978) and higher P and K uptake by corn (Warmer and Termeer, 2005) indicating a residual effect on soil nutrient content. Magnesium uptake was higher (3.44 kg ha^{-1}) in treatment T_7 (PS compost @ 10 t ha^{-1}). This was followed by 3.34 kg ha^{-1} in treatment T_9 (50 % N through PS + 50% N through FYM) and 2.31 kg ha^{-1} in treatment T_6 (MEES compost @ 10 t ha^{-1}) which were statistically on par with each other. No significant change with respect to the calcium uptake by plants, though increases were produced on addition of compost (Gallardo-Lara and Nogales, 1987). The addition of organics and composts has increased the soil Mg and S concentrations contributing to an increase in the concentration of Mg and S in cowpea. Addition of MSW compost increased total soil Mg concentrations when compared to unamended control soil, which in turn increased Swiss chard and basil Mg concentrations (Zheljazkov and Warman, 2004).

The higher uptake of micronutrients (iron, manganese, zinc and copper) by cowpea (71.96, 35.43, 20.98 and 11.70 g ha^{-1} Fe, Mn, Zn and Cu respectively) was recorded in treatment T_9 (50 % N through PS + 50% N through FYM). Significantly lower uptake of Fe, Mn, Zn and Cu (15.81, 12.68, 5.28 and 2.06 g ha^{-1}) was observed in treatment T_2 (100 % NPK + FYM @ 5 t ha^{-1}).The treatments T_6 (MEES compost @ 10 t ha^{-1}) and T_7 (PS compost @ 10 t ha^{-1}) recorded an uptake of 43.30 and 57.16 g ha^{-1} of iron respectively. Application of composts has resulted in an increase in the uptake of Fe, Mn, Zn and Cu by vegetables (Sterrett and Chaney, 1982) and an increase in Zn uptake by corn (Terman *et al.*, 1973). Higher uptake of nutrients by cowpea in organic amended plots could be attributed to higher content of nutrients in organic amendments which in turn is released during decomposition resulting in higher content as a result of mineralisation from composts and soil. The higher uptake also has resulted from the higher yield of cowpea and content of nutrients present in the compost applied plots. Higher uptake of N, P and K (31.42, 5.38 and 36.21 kg ha^{-1}) by cowpea haulm was recorded in treatment T_9 (50 % N through PS + 50 % N through FYM), which was on par with treatment T_7 (PS Compost @ 10 t ha^{-1}). Similar results of increased uptake of N, P and K by crops on addition of organic amendments or composts to soil (deHaan 1981; Asija *et al.*, 1984 and Soumare *et al.*, 2003a)

The uptake of secondary nutrients (calcium, magnesium and sulphur) and micronutrients varied significantly between different treatments. The uptake of Ca (24.23 kg ha^{-1}), Mg (10.80 kg ha^{-1}), S (6.19 kg ha^{-1}) and Fe, Mn, Zn and Cu was higher in treatment T_9 (50 % N through PS + 50 % N through FYM) followed by treatment T_7 (PS compost @ 10 t ha^{-1}) which were statistically on par with each other. Application of MSW compost increased S uptake by timothy and red clover (Zheljazkov *et al.*, 2006); increased Swiss chard and basil Mg concentrations (Zheljazkov and Warman, 2004); increased the uptake of micronutrients by corn plants (Roghanian *et al.*, 2012). Wong *et al.*, (1983) and Terman *et al.*, (1973) reported that application of highly carbonaceous compost supplied considerable zinc to plants and thereby increased Zn uptake. Iron and Mn uptake by cowpea receiving the compost alone, was higher than that of no compost treatments which indicated that the compost used is capable of supplying plant available Fe and Mn. Higher uptake of nutrients is due to the higher content of nutrients present in haulm of cowpea as well as the higher haulm yield. Lower uptake in treatment T_2 (100 % NPK + FYM @ 5 t ha^{-1}) is a result of lower yield and lower concentration of nutrients in that exhibiting only the residual effect of farm yard manure. The lower dose of farm yard manure in comparison to that of other treatments has resulted in their poor performance on cowpea growth, yield, nutrients concentration as well as uptake.

Enzyme industrial waste – municipal solid waste composts proved to have a positive residual effect on cowpea growth, yield, concentration and uptake of nutrients. The application of composts resulted in significant differences in nutrient concentration in cowpea resulting from an increased mineralization of nutrients from the composts. The source of municipal solid waste raises a strong concern of heavy metal accumulation and uptake on crop growth, though the content was well below the detectable limits in this study. The residual effects, particularly that of concentration and uptake of heavy metals must be evaluated before recommending the use of these enzyme industrial waste – municipal solid waste composts as source of organic fertilizer, for which, long term studies are unavoidable. Thus, further research is necessary before recommending this compost to understand its effects on soil properties and crop growth, yield and quality in the long run with emphasis on heavy metals accumulation and uptake.

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How to cite this article:

Karthika, K.S., V.R.R. Parama, C.T. Subbarayappa, B. Hemalatha and Vidya, C.S. 2018. Residual Effect of Enzyme Industrial Waste-Municipal Solid Waste Composts Application on Growth, Yield, Content and Uptake of Nutrients by Cowpea. *Int.J.Curr.Microbiol.App.Sci.* 7(10): 1386-1395. doi: https://doi.org/10.20546/ijcmas.2018.710.154