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Vermicomposting of Sewage Sludge for Reasonable Nutrient Recovery under different C/N ratios

Presenter

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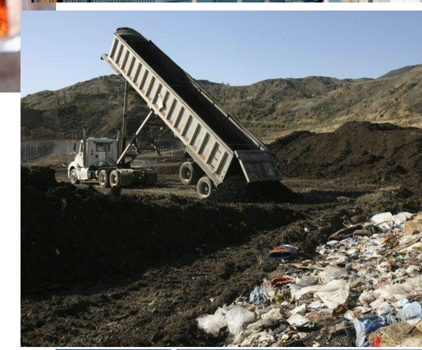
INTRODUCTION

- Sewage Sludge(SS) is a residual, semi-solid material that produced as a by-product during **WWT/MWW**

- Globally, the amount of SS is increasing as the urban population grows.

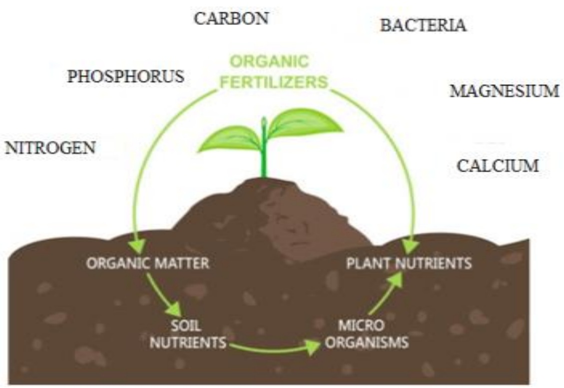
- The total SS volume produced in
  - ✓EU 9 million tons (in 2010)
  - ✓China 3 million tons(in 2006),
  - ✓USA 6.5 million tons(in 2004) DM/year (Rékási et al., 2019)



- Historically, SS has been disposed by incineration, Landfilling, ocean disposal (Bridle & Skrypski-Mantele, 2000)

INTRO…

- ❑ Nowadays, the most widespread method for SS has become an agricultural application, because SS is,



- ✓ rich in **OM**, **plant nutrients (macro & micro-nutrients)**
- ✓ the most economical outlet for compared to incineration and landfilling (Chen et al. 2014).

- ❑ Therefore, SS can potentially substitute fertilizer and increase DMY of many crops (Guilayn et al., 2019).

- ❑ However, it is absolutely essential for SS to undergo additional treatment before being applied for agronomic use.

- ✓ Due to the presence of certain soil contaminants, such as organic compounds (e.g. **PCBs, PAHs), heavy metals (Pb, Cd, As, Cr, Ni, CO …)** and **human pathogens (Hait and Tare, 2012)**.

INTRO…

- Composting & vermicomposting are ideal for SS stabilisation, and these process are low-cost and environmentally-friendly (Hanc and Vasak, 2015).

- During these processes, C/N ratio is important because microorganisms require a good balance of C & N to remain active and has a significant influence on OM, as well as compost maturity (Akratos et al., 2017; Guo et al., 2012).

- The ideal initial C/N ratio range from 25 to 30 (Kumar et al., 2010), But other authors claim that international technical standards require a C/N range of 20 to 30 (Vochozka et al., 2017) and 25 to 35 (Akratos et al., 2017).

- A high initial C/N causes the process to start slowly and take longer to compost, whereas a low C/N results in high NH3 and increase N loss (Oudart, 2013).

- However, there is a lack of data and very few studies on the effects of different C/N ratios on plant nutrient recovery during SS vermicomposting/composting.

- Therefore, the objective of this study was to evaluate the effects of C/N ratios on plant nutrient recovery during vermicomposting and whether the vermicompost prepared from SS contains more plant-available nutrients than compost at different C/N ratios.

MATERIALS AND METHODS

Experimental Setup

- Mixtures treated were by
  - ✓Composting(C)
  - ✓Vermicomposting(VC)

for 120 days temperature 22°C, relative humidity 70-80%)

(after 14 days of pre-composted) using *E. andrei*.

Table 1. Experimental setup

Variants	SS (%)	PWS (%)	C/N ratios
Mix1	100	0	6:1
Mix2	75	25	18:1
Mix3	50	50	28:1
Mix4	25	75	38:1

NB: Three replications were conducted for all the treatments

❖ Sewage sludge(SS): Pelletized wheat straw(PWS) (dry weight basis

❖ All parameters were analysed using the standard methods for each one

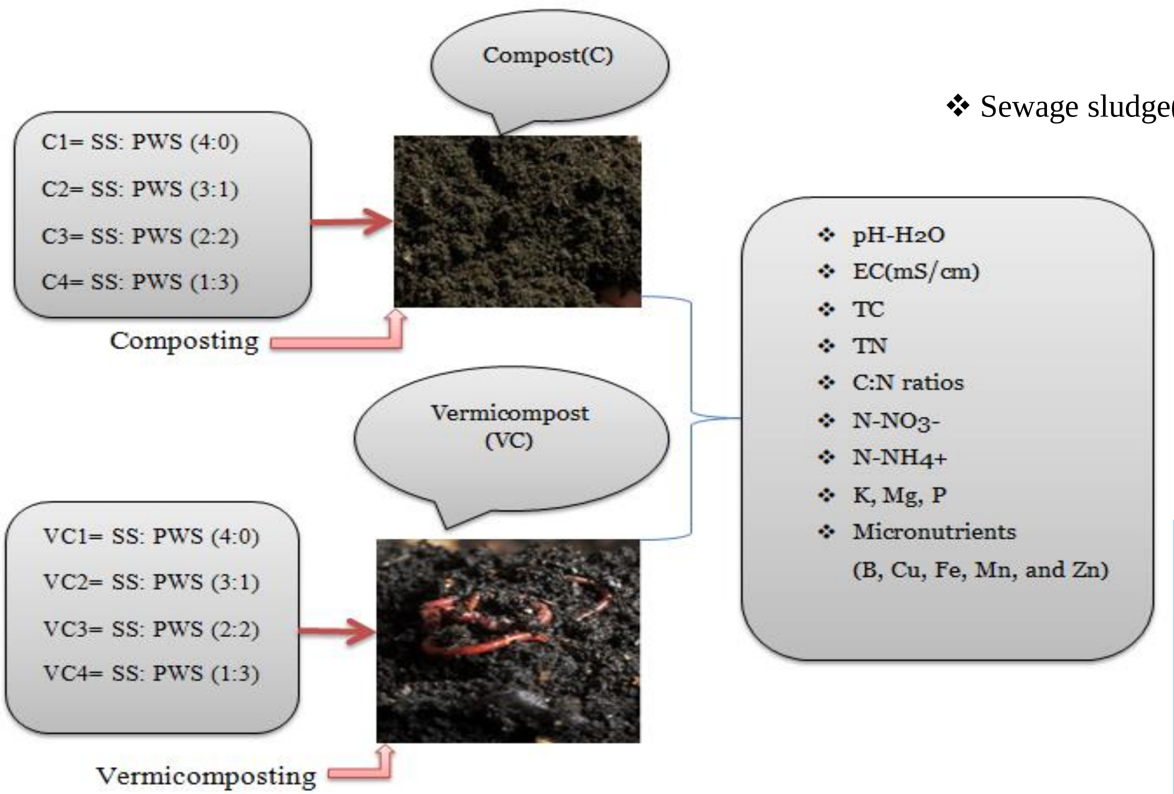


Fig.1. An illustration of the experimental study design

STATISTICAL ANALYSES

- Statistical analyses were carried out using the R statistical package version 4.0.2 and STATISTICA 12 software (StatSoft, Tulsa, USA).

- Two ANOVA was used to test whether there was a significant difference between the composting methods and the C/N ratios in the properties of the final product.

- Tukey's honestly significant difference (HSD) test was used to compare the treatment means where the effect of the factors were significant at $p < 0.05$.

RESULTS AND DISCUSSION

1. pH and electrical conductivity(EC)

Table 2. Changes in pH, EC after 120 days of composting and vermicomposting (±sd)

$pH(H_2O)$				
Variants	Initial	Compost	Vermicompost	%Change over compost
Mix1(6:1)	6.9±0.03	8.6±0.02a	5.7±0.49a	-33.7ab
Mix2(18:1)	7.3±0.11	8.4±0.12ab	5.2±0.11a	-38.1a
Mix3(28:1)	7.6±0.25	8.2±0.09ab	6.0±0.45a	-26.8b
Mix4(38:1)	7.8±0.38	7.9±0.12c	5.8±0.18a	-25.6b
EC(mS/cm)				
Variants	Initial	Compost	Vermicompost	%Change over compost
Mix1(6:1)	0.617±0.11	2.12±0.31a	2.16±2.10a	1.9d
Mix2(18:1)	0.633±0.08	1.30±0.06a	2.10±0.42a	61.5c
Mix3(28:1)	0.649±0.06	1.20±0.22a	2.25±0.32a	87.5b
Mix4(38:1)	0.664±0.05	0.68±0.04b	2.28±0.49a	235.3a

Mean value followed by different letters is statistically different (ANOVA; Tukey's test, $P < 0.05$)

- ❖ The release of low-molecular-weight organic acids(humic acids) from organic decomposition, increase in nitrification into nitrites/nitrates & conversion of organic phosphorus into orthophosphates can decrease the pH (Sharma and Garg, 2018).

- ❖ The increase of EC in vermicompost was due to the breakdown of OM by the activities of earthworms and released minerals such as exchangeable Ca, Mg, K, and P in their available forms as cations (Negi and Suthar, 2018).

2. TC, TN, C: N Ratios

Table 3. Changes in TC, TN, and C/N ratio after 120 days of composting and vermicomposting (±sd)

	TC (%)			
Variants	Initial	Compost	Vermicompost	%Change over compost
Mix1(6:1)	32.9±0.26	26.5±1.6d	25.78±7.08b	-2.72c
Mix2(18:1)	35.36±0.23	30.1±0.2b	28.85±0.3ab	-4.15a
Mix3(28:1)	37.77±0.24	32.1±0.6c	31.86±0.63ab	-0.75d
Mix4(38:1)	40.18±0.29	35.9±0.9a	34.64±0.17a	-3.5b
	TN (%)			
Variants	Initial	Compost	Vermicompost	%Change over compost
Mix1(6:1)	5.36±0.03	4.1±0.2a	3.19±0.89a	-22.2a
Mix2(18:1)	1.98±0.21	3.5±0.1b	2.89±0.07a	-16.18b
Mix3(28:1)	1.34±0.07	3.3±0.1ab	2.82±0.12a	-17.43b
Mix4(38:1)	1.05±0.05	3.1±0.1ab	3.05±0.09a	-1.6c
	C/N ratios			
Variants	Initial	Compost	Vermicompost	%Change over compost
Mix1(6:1)	6.14±0.04	6.5±0.2d	8.10±0.23c	24.6a
Mix2(18:1)	18.03±1.92	8.7±0.2c	9.96±0.28b	14.48b
Mix3(28:1)	28.17±1.43	9.7±0.5b	11.32±0.23a	16.7b
Mix4(38:1)	38.36±2.03	11.34±0.2a	11.70±0.35a	3.17c

Mean value followed by different letters is statistically different (ANOVA; Tukey's test, $P < 0.05$)

- The reduction in TC owed to the respiration of microbes and the stabilization of OM by earthworms (Hanc, et al., 2017).
- The higher values of TN in compost and could be due to OC loss during composting(Huang et al., 2004).
- The C/N ratio indicates the maturity of vermicompost because it reflects the rates of stabilization and mineralization during vermicomposting (Arumugam et al., 2018; Srivastava et al., 2020).
- The increased in N content and OM degradation also contribute to the decrease in the C: N ratio (Devi et al., 2020)

3. Mineral N (N-NO3-, N-NH4+,mg/kg dw)

Table 4. Changes in N-NO3-, and N-NH4+ after 120 days of composting and vermicomposting

$N\text{-}NO_3^-$ (mg/kg DW)					
Variants	Initial	Compost	%Increase	Vermicompost	%Increase
Mix1 (6:1)	2.26±0	414±55	99.45	5169± 432	99.96
Mix2 (18:1)	6.02±0.4	936±58	99.36	5523±732	99.89
Mix3 (28:1)	9.78±0.7	1081±14	99.10	4831± 547	99.80
Mix4 (38:1)	13.54±1.1	1317±154	98.97	4530±49	99.70
$N\text{-}NH_4^+$ (mg/kg DW)					
Variants	Initial	Compost		Vermicompost	
Mix1 (6:1)	1072±52	1381±147	22.18	557± 116	-92.46
Mix2 (18:1)	815±39.58	950±121	14.21	782± 5.7	-4.22
Mix3 (28:1)	557±26.77	835±403	33.29	825±36	38.48
Mix4 (38:1)	300±14.21	1323±40	77.32	649±129	53.78

Mean value followed by different letters is statistically different (ANOVA; Tukey's test, $P < 0.05$)

- ❖ The $N\text{-}NO_3^-$ levels were increased and $N\text{-}NH_4^+$ decreased during vermicomposting (Hait and Tare,2012).
- ❖ Signification proportion of $N\text{-}NH_4^+$ can be converted to $N\text{-}NO_3^-$ during the nitrification process and certain portion of $N\text{-}NH_4^+$ could be also volatilized in the form of NH_3.
- ❖ The nitrate content increased, owing to the conversion of NH_3 to nitrate via oxidation by nitrifying bacteria (Lv et al., 2018).
- ❖ The reduction of $N\text{-}NH_4^+$ indicated compost maturity(Tognetti et al., 2007)

Available Macronutrients(K, Mg, P)

Table 5: Changes in available Potassium(K) after 120 days of composting and vermicomposting

Variants	Initial	Compost	%Increase	Vermicompost	%Increase	%Change over compost
Mix1 (6:1)	2090±46	2287±100c	9	6467±333d	68	183a
Mix2 (18:1)	2923±63	5362±2737b	45	8496±205c	66	58c
Mix3 (28:1)	3757±107	5193±162b	28	10160±712b	63	96b
Mix4 (38:1)	4590±157	7847±211a	42	11971±160a	62	53c

Mean value followed by different letters is statistically different (ANOVA; Tukey's test, $P < 0.05$). Values indicate mean ± sd ($n = 3$).

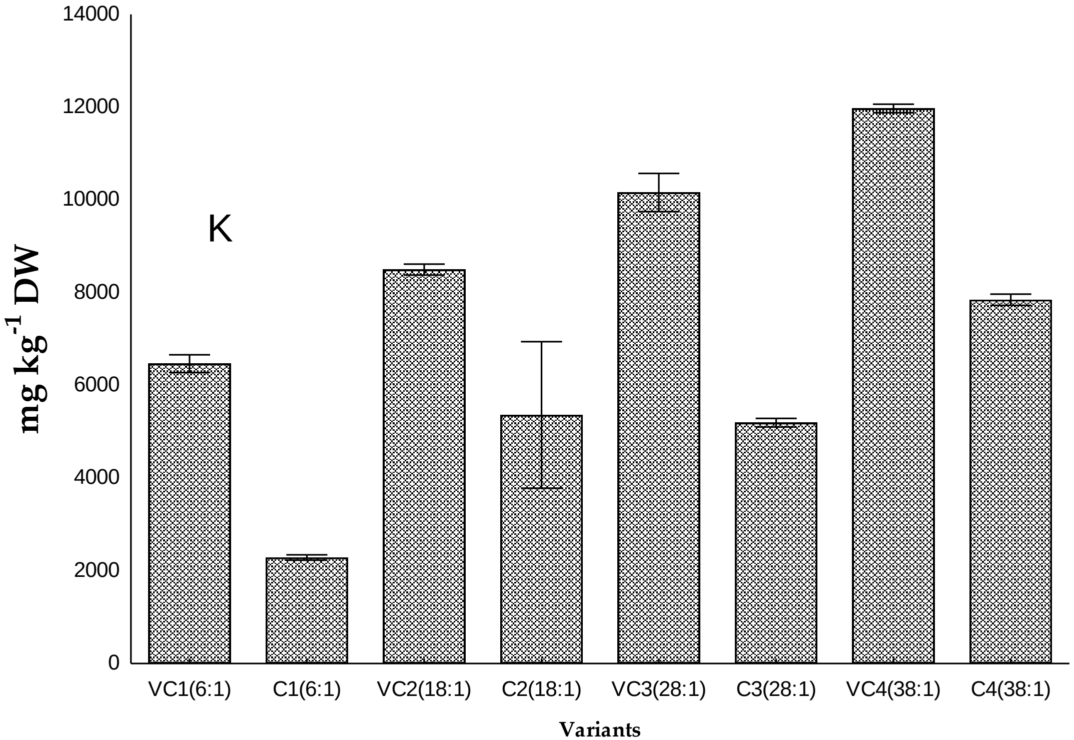


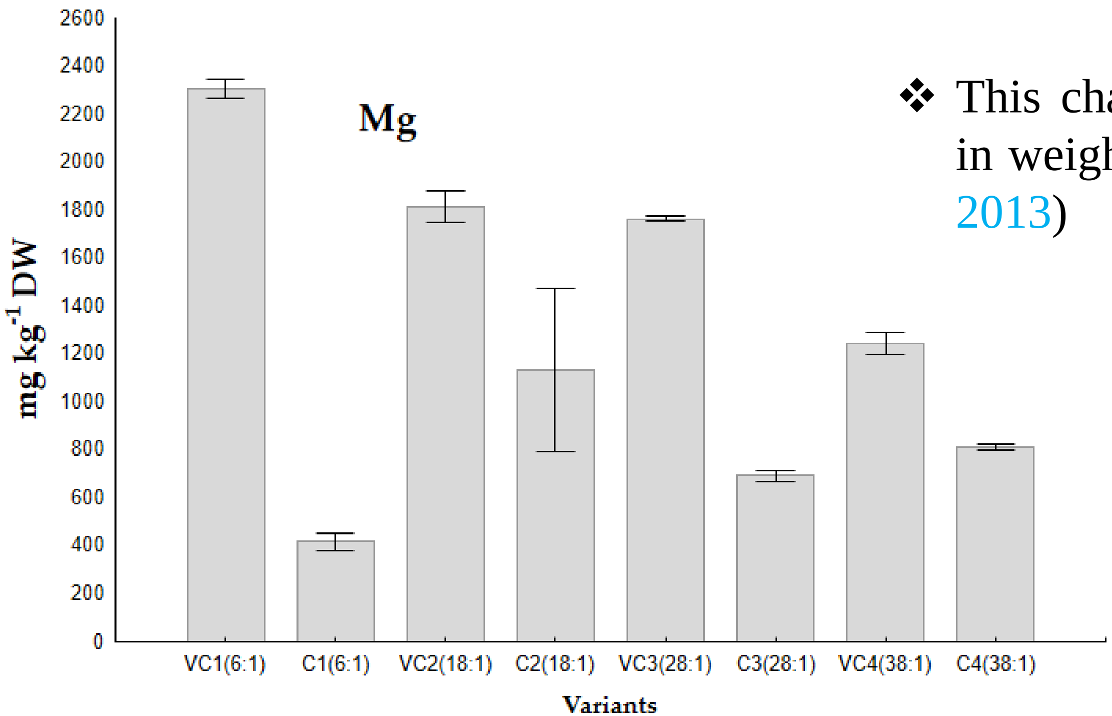
Fig.2. Available K per C/N ratios

- ✓ K may increased due to the solubilisation of organically bound K caused by acid production by microorganisms (Garg et al., 2006).
- ✓ an earthworm's intestine may aid in the release of K in vermicompost (Khatua et al., 2018).
- ✓ These factors may have contributed to an overall increase in K

Table 6: Changes in available Magnesium(Mg) after 120 days of composting and vermicomposting

Variants	Initial	Compost	%Increase	Vermicompost	%Increase	%Change over compost
Mix1 (6:1)	502±15	517±60d	3	2307±71c	78	346a
Mix2 (18:1)	519±112	1133±594a	54	1813±115a	71	60c
Mix3 (28:1)	536±9	692±42c	23	1764±15b	70	155b
Mix4 (38:1)	552±6	811±23b	32	1247±81d	56	54c

Mean value followed by different letters is statistically different (ANOVA; Tukey's test, $P < 0.05$). Values indicate mean ± sd ($n = 3$).



- ❖ This change was associated with a reduction in weight and organic matter (Wani and Rao, 2013)

Fig.3.Available Mg per C/N ratios

Table 7: Changes in available phosphorus(P) after 120 days of composting and vermicomposting

Variants	Initial	Compost	%Increase	Vermicompost	%Increase	%Change over compost
Mix1 (6:1)	371±92	1422±79a	74	924±75c	60	–35b
Mix2 (18:1)	339±62	1279±325b	73	852±49d	60	–33b
Mix3 (28:1)	307±34	1158±29c	74	1153±12b	73	–0.43c
Mix4 (38:1)	275±14	816±114d	66	1427±95a	81	754a

Mean value followed by different letters is statistically different (ANOVA; Tukey's test, $P < 0.05$). Values indicate mean ± sd ($n = 3$).

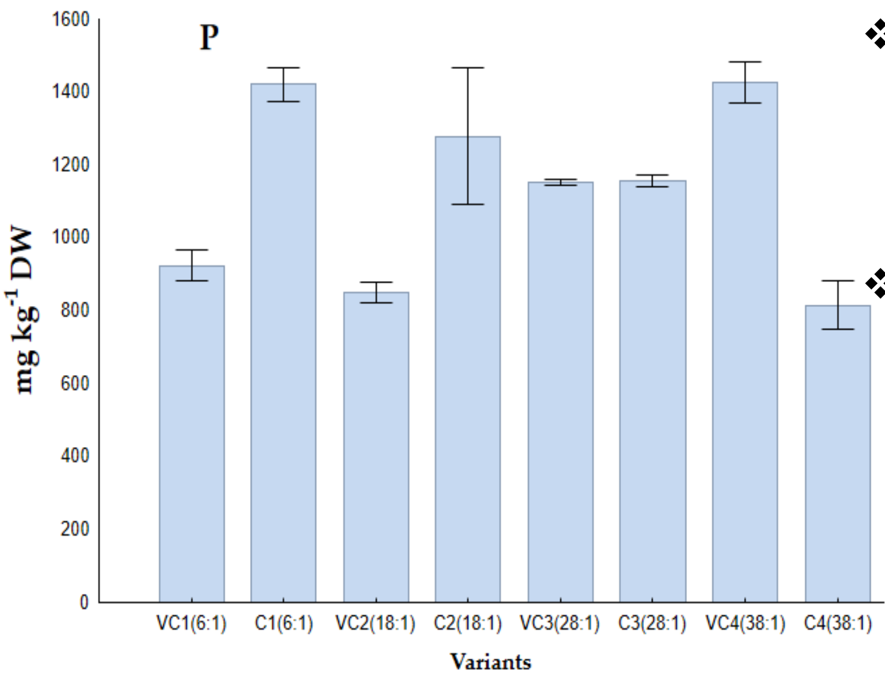


Fig.4. Available P per C/N ratios

- The presence of earthworm gut phosphatase and P-solubilising MO in the worm casts, enhance the release of P in various forms, responsible for the increase in P (Deka et al., 2011).
- The pH reduction could also have enhanced the solubilisation of P and the release of organically bound phosphate and thus increased its concentration in the final product (Devi et al., 2020).

Available Micronutrients

Table 8: Changes in available Boron(B) after 120 days of composting and vermicomposting

Variants	Initial	Compost	%Increase	Vermicompost	%Increase	%Change over compost
Mix1 (6:1)	1.62±0.05	2.06±0.07a	21	8.30±0.38a	80	303a
Mix2 (18:1)	1.46±0.04	4.40±2.42a	67	6.52±0.54a	78	48d
Mix3 (28:1)	1.29±0.04	3.23±0.21a	60	7.19±1.74a	82	123b
Mix4 (38:1)	1.13±0.55	3.21±0.13a	65	6.4±1.30a	82	99c

Mean value followed by different letters is statistically different (ANOVA; Tukey's test, $P < 0.05$). Values indicate mean ± sd ($n = 3$).

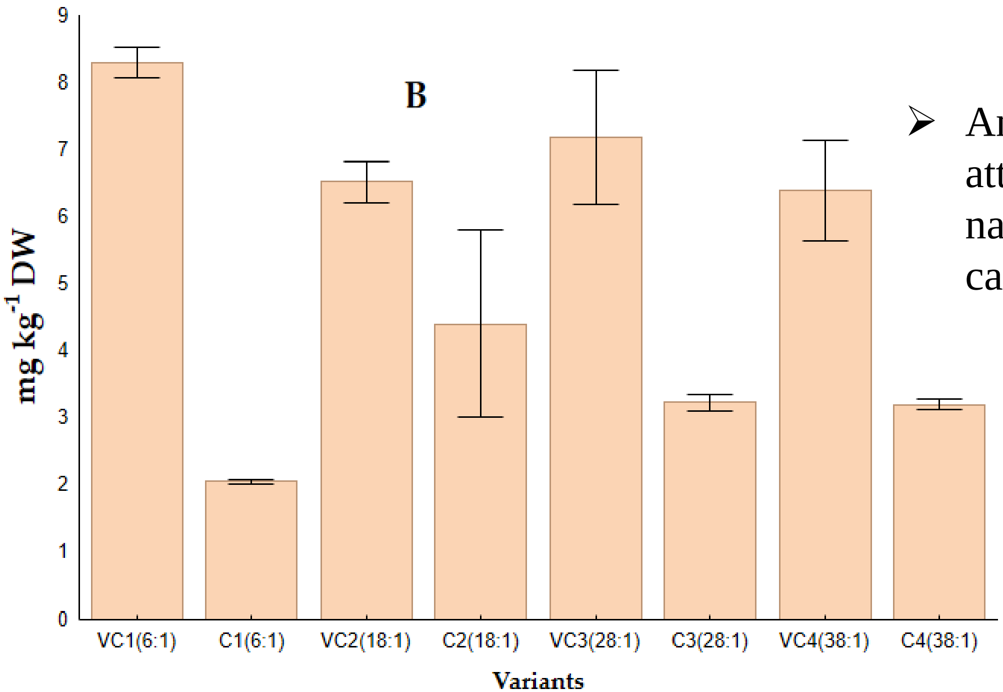


Fig.5. Available B per C/N ratios

- An increase in B during vermicomposting is attributed to the catabolic activity of earthworms, namely carbonic anhydrase found in their calciferous glands (Manyuchi and Phiri, 2013).

Table 9: Changes in available Copper(Cu) after 120 days of composting and vermicomposting

Variants	Initial	Compost	%increase	Vermicompost	%Increase	%Change over compost
Mix1 (6:1)	5.66±3.30	15.17±1.55a	63	27.6±0.36a	79	82a
Mix2 (18:1)	4.35±2.47	22.3±10.91a	80	29.13±1.61a	85	31b
Mix3 (28:1)	3.05±1.64	20.58±0.78a	85	24.3±2.74a	87	18c
Mix4 (38:1)	1.75±0.67	16.2±1.50a	89	16.62±2.84b	89	3d

Mean value followed by different letters is statistically different (ANOVA; Tukey's test, $P < 0.05$). Values indicate mean ± sd ($n = 3$).

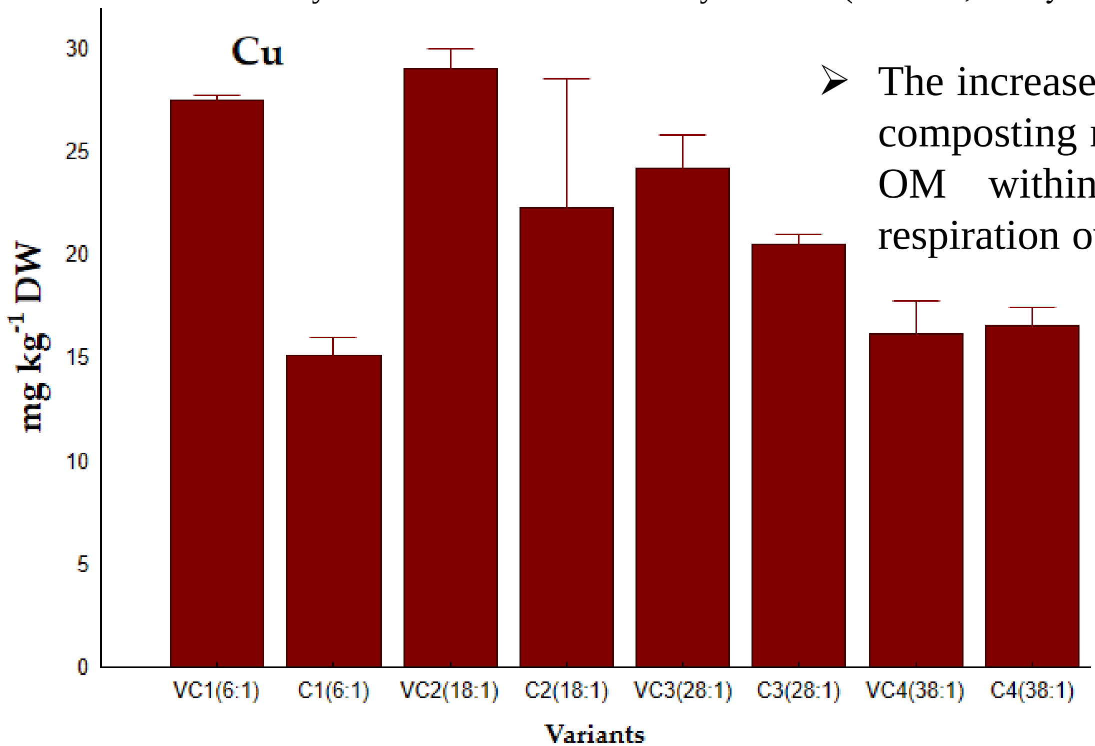


Fig.6. Available Cu per C/N ratios

- The increase in concentration of Cu throughout the vermi composting might be due to progressive mineralization of OM within the vermicompost, and loss through respiration over time (Amir et al., 2005).

Table 10: Changes in available Iron(Fe) after 120 days of composting and vermicomposting

Variants	Initial	Compost	%Increase	Vermicompost	%Increase	%Change over compost
Mix1 (6:1)	358±12	798±27a	55	389±49a	8	–51d
Mix2 (18:1)	270±9	659±191b	59	358±28b	25	–46c
Mix3 (28:1)	183±6	358±33d	49	349±90b	48	–2a
Mix4 (38:1)	96±45	385±19c	75	284±58c	66	–26b

Mean value followed by different letters is statistically different (ANOVA; Tukey's test, $P < 0.05$). Values indicate mean ± sd ($n = 3$).

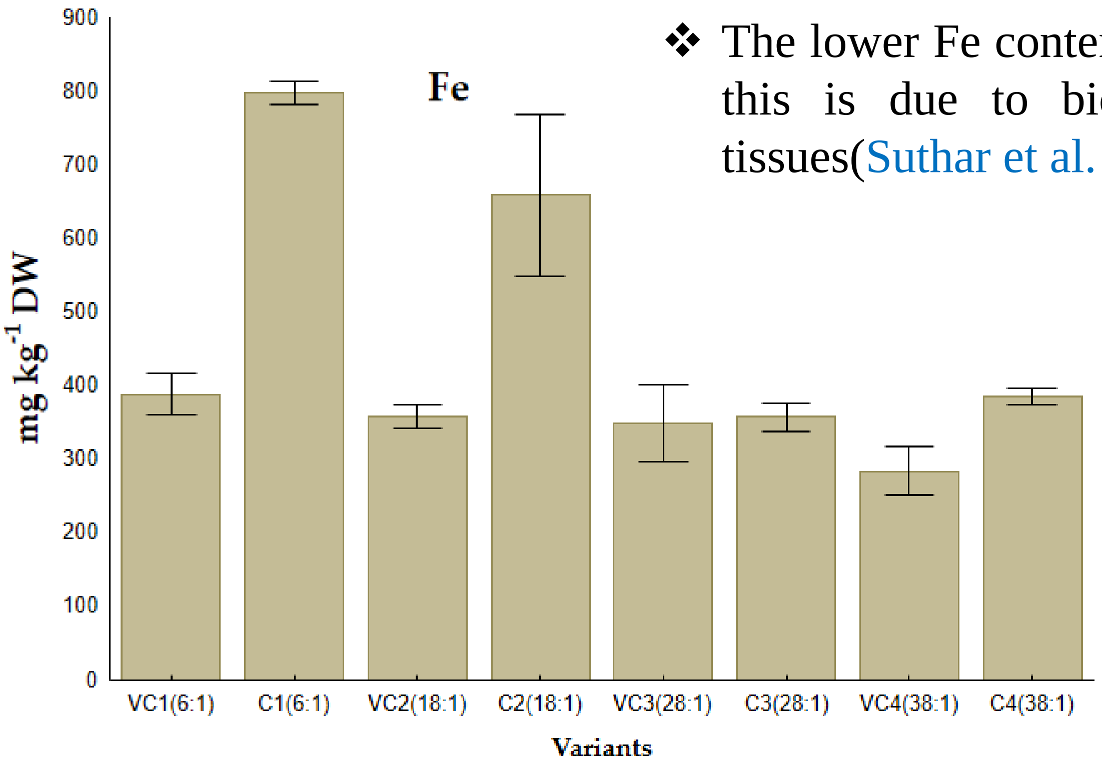


Fig.7. Available Fe per C/N ratios

❖ The lower Fe contents found in vermicompost suggest that this is due to bio-accumulation of Fe in earthworm tissues(Suthar et al. 2014).

Table 11: Changes in available Manganese(Mn) after 120 days of composting and vermicomposting

Variants	Initial	Compost	%Increase	Vermicompost	%Increase	%Change over compost
Mix1 (6:1)	252±4	161±6c	-56	245±19a	-3	52a
Mix2 (18:1)	195±2	333±176a	41	209±77b	7	–37b
Mix3 (28:1)	139±1	226±6b	39	155±32c	11	–31b
Mix4 (38:1)	82±40	160±7c	49	113±17d	27	–30c

Mean value followed by different letters is statistically different (ANOVA; Tukey's test, $P < 0.05$). Values indicate mean ± sd ($n = 3$).

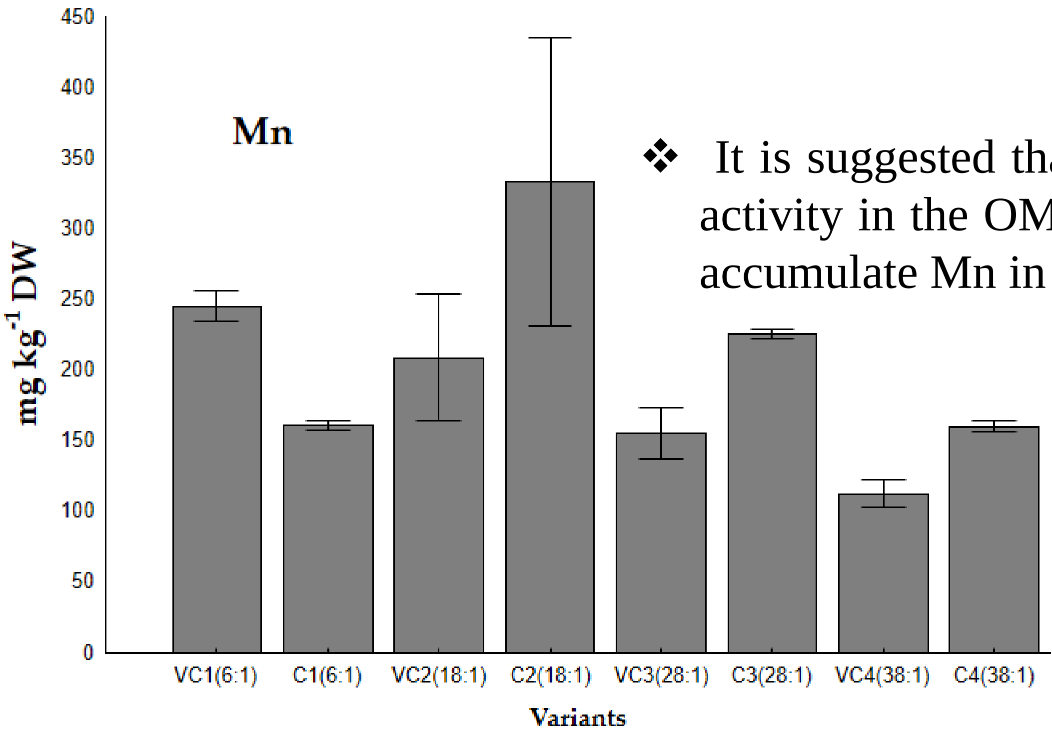


Fig.8. Available Mn per C/N ratios

❖ It is suggested that Mn loss was related to the earthworm activity in the OM decomposition that the earthworms can accumulate Mn in their tissues(Suthar and Singh, 2008).

Table 12: Changes in available Zinc(Zn) after 120 days of composting and vermicomposting

Variants	Initial	Compost	%Increase	Vermicompost	%Increase	%Change over compost
Mix1 (6:1)	103±9	194±16c	47	257±6a	60	32a
Mix2 (18:1)	79±7	356±171a	78	250±26b	68	–30a
Mix3 (28:1)	55±4	252±6b	78	195±16c	72	–23b
Mix4 (38:1)	31±13	162±6d	81	145±25d	79	–10c

Mean value followed by different letters is statistically different (ANOVA; Tukey's test, $P < 0.05$). Values indicate mean ± sd ($n = 3$).

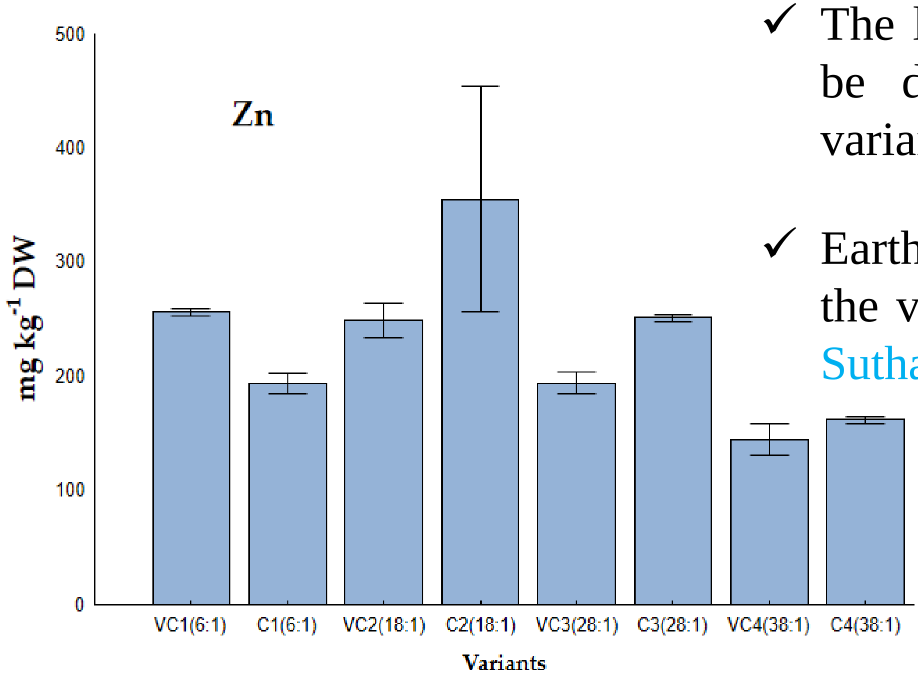


Fig.9. Available Zn per C/N ratios

- ✓ The lower Zn content of vermicompost was found to be directly related to earthworm activity in the variants.
- ✓ Earthworms can accumulate Zn in their tissues during the vermicomposting process (Gupta and Garg, 2008; Suthar, 2008)

CONCLUSION

- Findings emphasize the significance of the C/N ratios, the composting and vermicomposting used in influencing the final products.

- Indeed, comparing the two final products derived from the same raw material, vermicomposting increased EC, K, Mg, N-NO_3^-,P, B, Cu.

- However, decreased pH, TC, TN, NH4+ (except VC3, VC4), P except(VC4), Fe, Mn and Zn except (VC1) over compost.

- Therefore, this study confirms that vermicomposting of SS mixed with PWS at 18:1 C/N ratios performed best, possibly due to their improved and favourable plant nutrients.

Acknowledgment

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Thank you very much for your Attention!!