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Effect of different zinc enriched organics on nutrient content and uptake by summer pearl millet [*Pennisetum glaucum* L.] on loamy sand

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Abstract
The present investigation was carried out to study the comparative efficiency of different Zn-enriched organics on crop yield and increase the fertilizer use efficiency in pearl millet (var. GHB-744). The enrichment of different organics was carried with Zn by composting the locally available organics *viz.*, farm yard manure (FYM), poultry manure (PM), vermicompost (VC) and biogas slurry (BGS) for six to seven weeks as required to complete the enrichment process. Nitrogen contents in seed and straw, Zn contents in seed and straw and protein content in seed were increased significantly due to application of 100% RDNP with 500 kg PM enriched with 5.0 kg Zn ha^{-1} (T_{12}). Nitrogen, potassium and zinc uptake by seed and straw and protein yield were significantly the highest due to application of 100% RDNP with 500 kg PM enriched with 5.0 kg Zn ha^{-1} (T_{12}). In Phosphorus uptake by seed and straw was significantly increased by the application of 100% RDNP with 500 kg PM enriched with 2.5 kg Zn ha^{-1} (T_{11}). An application of 100% RDNP with 500 kg PM enriched with 5.0 kg Zn ha^{-1} (T_{12}) enhanced organic carbon status and availability of nutrients like nitrogen, Phosphate, Potash and Zn in soil after harvest.

Keywords: Enriched organics, farm yard manure, poultry manure, vermicompost and biogas slurry

Introduction
Zinc being one of the essential micronutrients, plays significant role in various enzymatic and physiological activities of the plant system. It is also essential for photosynthesis and N-metabolism. It is important for stability of cytoplasmic ribosomes, cell division, Dehydrogenage, proteinase and Peptidage enzymes and also helps in the synthesis of protein and carotene. Crops utilize very low amounts of fertilizer-Zn but very high doses of fertilizer Zn are often applied to correct Zn deficiencies in crops due to a high fixation of applied Zn in the soil. Fertilizer-Zn use efficiency is hardly 1 to 5 percent. The integrated use of micronutrients in combination with organic manures (8-10 t ha^{-1}) serves as a better option due to high chelation and slow availability which prevent micronutrient losses through precipitation, fixation, oxidation and leaching.
Organics may serve as a source of micronutrients and complexing agent. On decomposition of organics numerous compounds like Humic acid, Fulvic acids and verities of biological substances including organic acids, polyphenols, amino acid crop produce, which improve the efficiency of applied nutrients. Thus, the Zn enriched organics are expected to provide beneficial effect on plant growth enriched nutrients for a longer time.
Soils of India has multiple nutrient deficiencies, mainly of N, P, K, S and Zn and their use have become essential to obtain optimum crop yield. As nearly half of the Indian soil are Zn deficient and 24 percent soils of Gujarat are Zn deficient and 58 percent soils of North Gujarat found deficient to medium in available Zn status. Zinc deficiency in agricultural soils affecting both yield and quality of crop. Severe Zn deficiency in the soil may cause yield losses up to 30 percent in cereals. Micronutrient deficiency in soil is either due to continuous removal of micronutrients from the soil by recently introduced fertilizer responsive and high yielding varieties of crops or use of micronutrient free high analysis fertilizers.

Material and Methods
Enrichment of organics with zinc sulphate
The enrichment process was started 60 days before their use in the *summer* experiment on pearl millet. The known quantity of organics was filled in pre-dung pits of 1.5×1.5×1.5 m^3 size. The organics were thoroughly mixed with the solution of $ZnSO_4$. $7H_2O$ having required concentration as per the enrichment treatments *viz*., 2.5 and 5.0 kg Zn through 500 kg of organics per hectare. The moisture percentage of organics after mixing with $ZnSO_4$. $7H_2O$ (except BGS) was kept at about 70 to 80 percent.

The starter inoculums of microorganisms in the form of cow dung slurry @ 1% was applied to boost up the microbiological activities for enhancement of natural process of composting to fix the externally added inorganic Zn into organically bound and naturally chelated form of Zn, a process called as enrichment of organics with Zn. The initial samples were collected and they were subjected to analysis to know the initial status of nutrient in different organics immediately before mixing with $ZnSO_4.7H_2O$ solution. The pit was covered by polythene sheet and allowed for decomposition. The mixture was turned over periodically (weekly) and moisture loss was maintained.

Table 1: Treatment details

Symbol	Treatments
T_1	100% RDNP + 500 kg FYM ha^{-1}
T_2	T_1 + 2.5 kg Zn ha^{-1}
T_3	T_1 + 5.0 kg Zn ha^{-1}
T_4	100% RDNP +500 kg VC ha^{-1}
T_5	100% RDNP +500 kg PM ha^{-1}
T_6	100% RDNP +500 kg BGS ha^{-1}
T_7	100% RDNP + 2.5 kg Zn-enriched FYM @ 500 kg ha^{-1}
T_8	100% RDNP + 5.0 kg Zn-enriched FYM @ 500 kg ha^{-1}
T_9	100% RDNP + 2.5 kg Zn-enriched VC @ 500 kg ha^{-1}
T_{10}	100% RDNP + 5.0 kg Zn-enriched VC @ 500 kg ha^{-1}
T_{11}	100% RDNP + 2.5 kg Zn-enriched PM @ 500 kg ha^{-1}
T_{12}	100% RDNP + 5.0 kg Zn-enriched PM @ 500 kg ha^{-1}
T_{13}	100% RDNP + 2.5 kg Zn-enriched BGS @ 500 kg ha^{-1}
T_{14}	100% RDNP + 5.0 kg Zn-enriched BGS @ 500 kg ha^{-1}

100% RDNP = 120 kg N ha^{-1} + 60 kg P_2O_5 ha^{-1}

Location, Climate and weather conditions

Geographically, Sardarkrushinagar is situated at 24º-19’ North latitude and 72º- 19’ East longitude with an elevation of 152.52 meters above the mean sea level. It is located in North Gujarat Agro-Climatic Zone.

This zone possesses a typical sub-tropical climatic conditions characterized by mild winters and moderate summer associated with high relative humidity during the months of July to September. The mean annual rainfall of the region is 630 mm, most of which is contributed by South, Western monsoon from July to September. In summer maximum temperature goes up to 44 ºC. May and June are the hottest months. Winters are fairly cold and dry. Wind velocity is high and stormy during summer. The metrological observation recorded at Agrometerolgy observatory, Chimanbhai Patel College of agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (Banaskantha) during cropping periods minimum temperature ranged between 16.2 ºC to 25.4 ºC, while the maximum temperature ranged between 34.6 ºC to 39.4 ºC during summer, 2015.

Physico-chemical properties of soil

The soil of experimental plot was categorised as loamy sand in texture. The soil was low in organic carbon, available nitrogen, medium in available phosphorus and high in potash. (Table 2).

Table 2: Initial Physico-chemical properties of the surface soil (0-15 cm) of the experimental plot.

	Properties	Value	Properties	Value
	Physical properties		**Chemical properties**	
1.	Coarse sand (%)	46.50	Soil pH (1:2.5)	7.58
2.	Fine sand (%)	40.25	EC (1:2.5) dS/m at 25°C	0.11
3.	Silt (%)	07.35	Organic carbon (%)	0.19
4.	Clay	05.90	Available N(kg/ha)	165.00
5	Texture class	Loamy sand	Available P_20_5(kg/ha)	42.60
6.	Taxonomy	*Typic Ustipsamments*	Available K_20 (kg/ha)	272.50
	DTPA extractable micronutrient Cations (mg/kg)			
1.	Zn	0.36		
2.	Mn	11.32		
3.	Fe	3.82		
4.	Cu	0.47		

Lay out

The experiment was laid out in Randomized Block Design.

Collection and preparation of plant and soil sample for chemical analysis

Plant samples

The treatment wise seed and straw samples were separately collected at the time of maturity of the crop. These samples were kept in brown paper bags for air draying. Thereafter, the samples were kept in oven at 60º to 70º C for drying till the constant weight was obtained. The dried samples were powdered in a grinder having stainless steel blades to avoid contamination of micronutrients. The chemical analysis of seed and straw samples were done separately for N, P, K, and Zn as per method.

The plant sample (seed and straw) were wet digested using di-acid mixture of HNO_3 and $HClO_4$ in 3:1 ratio (Johnson and Ulrich, 1959). The acid extract prepared after digestion was used for estimation of *viz*., P, K, Fe, Zn, Cu and Mn for their total contents by following analytical procedure as shown in table 3. The total N in grain and straw was estimated by Kjeldahl method using N analyzer (KELPLUS model). Double distilled water was used for micronutrient determination. All the chemical used were of ‘AR’ grade.

Soil Sample

To know the nutrient status of soil at harvest, a representative soil sample (0-15 cm depth) from five spots of each plot after harvest of bajara crop were collected composite and air dried in shade. These samples were then ground using wooden mortar and pestle and passed through 2 mm sieve and were analysed for available N, P, K, and Zn as per standard analytical method.

Table 3: Methods for plant analysis

Element	Methods	Reference
Nitrogena (%)	Modified Kjeldhal's digestion method	Waranke and Barber (1974) [15].
Phosphorous (%)	Vanadomolybdo phosphoric yellow colour method in nitric acid system	Jackson (1973) [3].
Potassium (%)	Flame photometry determination	Jackson (1973) [3].
Fe, Zn, Cu, Mn (mg kg^{-1})	By Atomic Absorption Spectrophotometer (Diacid digestion)	Lindsay and Norvell, (1978)

Table 4: Methods for soil analysis

Element	Methods	Reference
Mechanical analysis	International pipette	Piper (1950) [9].
pH (1:2.5) (soil: water)	Potentiometric	Jackson (1973) [3].
EC (1:2.5) soil:water at 25 ºC	Conductometric	Jackson (1973) [3].
Available Nitrogen (kg ha^{-1})	Alkaline $KMnO_4$ method	Subbiah and Asija (1956) [13].
Available P_2O_5 (kg ha^{-1})	Extraction: 0.5 M NaHCO3 (pH 8.5)	Olsen *et al*., (1954) [7].
	Estimation: Colorimetric	
Available K_2O (kg ha^{-1})	Extraction: 1 N NH4OAc (pH 7.0)	Jackson (1973) [3].
	Estimation: Flame photometric	
Organic carbon (%)	Walkley and Black's wet oxidation method	Jackson (1973) [3].
Available Fe, Zn, Cu, Mn (mg kg^{-1})	(a) Extraction: 0.005 M DTPA (pH 7.3)	Lindsay and Norvell (1978) [5].
	(b) Estimation: Atomic Absorption Spectrophotometric (Model: Elico SL 194)	

Computation of nutrient content and uptake

The concentration of all nutrients determined in plant was expressed in percent for major nutrients (N, P and K) and in mg kg^{-1} for micronutrient (Cu, Fe, Zn, MN).

The uptake of this nutrients was computed by using the following formula:

For macronutrients

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Yield (kg ha}^{-1}\text{)}}{100}$$

For micronutrients

$$\text{Nutrient uptake (g ha}^{-1}\text{)} = \frac{\text{Nutrient content (mg/ha)} \times \text{Yield (kg ha}^{-1}\text{)}}{1000}$$

Results and Discussion

Nutrients Content and uptake

N, P and K content in seed and straw

The N content in seed and straw (Table 2) were significantly influenced due to different treatments. The N contents in seed and straw was significantly improved under the treatment of 100 percent recommended dose of fertilizer along with 500 kg poultry manure ha^{-1} enriched with 5.0 kg Zn (T_{12}) as compared to Zn alone or enriched with Zn treatment, but it remained at par with T_{11} and T_{10} in case of N content in seed and straw. An increase in N content in seed and straw was 15.09 and 50 percent, respectively due to treatment of Zn enriched PM @ 5.0 kg ha^{-1} over T_1. Phosphorus and potassium content of pearl millet seed and straw did not differed significantly by different zinc enriched treatments.

The application of zinc in the soil deficient in Zn content increased the availability of zinc in rhizosphere. The beneficial role of zinc in increasing the cation exchange capacity of roots helped in increased absorption of nutrients from the soil. Further, the beneficial role of zinc in chlorophyll formation, regulating the auxin concentration and its stimulatory effect on most of physiological and metabolic process of plant might have helped the plants in absorption of greater amount of nutrients from soil. Thus the favourable influence of zinc on photosynthesis and metabolic process augment the production of photosynthates and their translocation to different plant parts including grain which ultimately increased the concentration of nutrients in seed and straw. The results are in cognizance with the finding on Sharma and Bhardwaj (1998) [11] and Dwivedi *et al.* (2001) [2].

The considerable increase in N contents in both seed and straw due to treatment of 100 percent RDF+ PM and VC enriched with two level of zinc 2.5 and 5.0 kg ha^{-1} (T_{12}, T_{11}, and T_{10}) could be attributed to fact that PM and VC has highest N contents as compared to FYM and BGS so that they added highest N content in soil had Favorable effect on soil properties that makes more N available during crop growth period. These result are close arrangement with these reported by Meena *et al*. (2015) [6].

Zn content in seed and straw

The overall effect of different Zn treatments on contents of micronutrient in seed and grain straw as direct effect has been shown in table 2. Further, the increase in Zn content was higher under Zn-enriched organics over straight Zn application. Zinc content in grain and straw were found significantly higher due to treatment receiving 100 percent recommended dose of fertilizer along with 500 kg poultry manure ha^{-1} enriched with 5.0 kg Zn (T_{12}) over rest of the treatments except T_{11}, T_{10}, T_{14}, T_{13} and T_8 in seed and T_{11} and T_{14} in straw.

It might be due Zn-enriched PM and VC utilized for enrichment contained more micronutrient than other organics and at the same time it showed its beneficial effects in mobilizing the native nutrients availability and thereby better crop growth resulting in higher utilization of the micronutrients. The higher micronutrient content especially that of Zn due to Zn-enriched organics along with NP application could also be attributed to the priming effect causing higher crop growth it also observed by Rathod *et al.* (2012) [10] and Meena *et al.* (2015) [6].

Table 5: Effect of different Zn-enriched organics on N, P, K, Zn content in seed and straw of pearl millet.

Treatment No.	N content (%)		P content (%)		K content (%)		Zn content (mg/kg)	
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
T_1	1.59	0.360	0.418	0.182	0.505	0.831	34.00	9.52
T_2	1.63	0.407	0.467	0.205	0.508	0.842	35.07	9.83
T_3	1.65	0.423	0.439	0.192	0.512	0.838	37.07	10.23
T_4	1.62	0.393	0.433	0.199	0.510	0.842	34.13	9.79
T_5	1.67	0.413	0.486	0.201	0.518	0.871	34.50	9.87
T_6	1.61	0.383	0.433	0.197	0.513	0.841	34.07	9.76
T_7	1.67	0.453	0.478	0.214	0.517	0.862	36.70	9.91
T_8	1.68	0.463	0.461	0.203	0.521	0.870	39.46	10.30
T_9	1.72	0.480	0.501	0.225	0.518	0.879	38.73	10.07
T_{10}	1.76	0.500	0.486	0.210	0.521	0.888	40.00	10.43
T_{11}	1.80	0.527	0.508	0.233	0.529	0.893	39.97	11.27
T_{12}	1.83	0.540	0.489	0.215	0.531	0.910	41.83	12.00
T_{13}	1.69	0.467	0.494	0.219	0.522	0.884	39.50	10.37
T_{14}	1.71	0.477	0.472	0.200	0.526	0.896	40.20	11.20
S.Em.$\pm$	0.030	0.015	0.02	0.01	0.006	0.018	1.03	0.28
C.D. at 5%	0.088	0.043	NS	NS	NS	NS	3.01	0.81
C.V. (%)	3.125	5.666	7.62	8.57	1.850	3.59	4.79	4.69

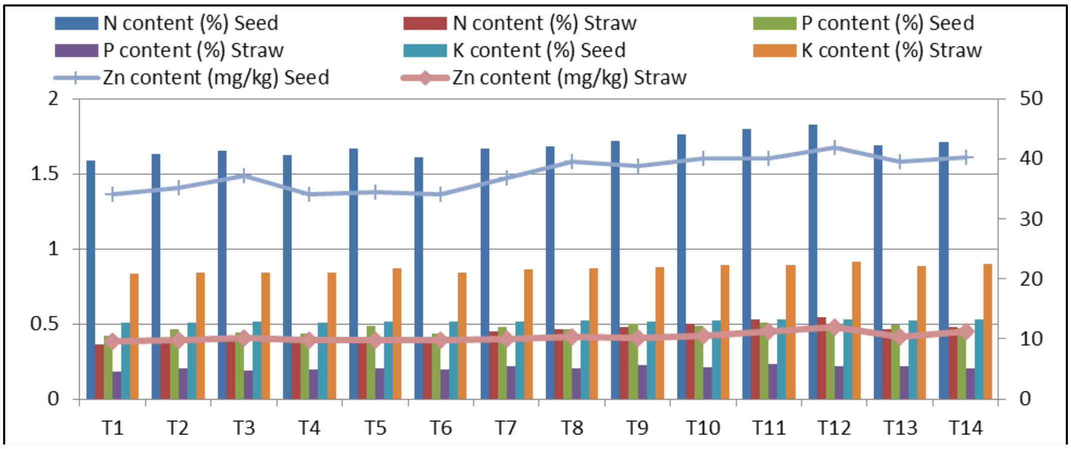

Fig 1: Effect of different Zn-enriched organics on N, P, K, Zn content in seed and straw of pearl millet

N, P and K uptake by seed and straw

The uptake of N, P and K (Table 5 to 6) by seed and straw significantly affected due to different treatments. Treatment T_{12} (100% RDNP along with 500 kg PM enriched with 5.0 kg Zn ha^{-1}) gave significantly the highest uptake of N and K by seed and straw over rest of the treatments except treatment T_{11}, T_{10} and T_9 in case of N and K uptake by seed and N uptake by straw in T_{11} and T_{10} treatments. The K uptake by straw the treatment 100% RDNP + 500 kg PM enriched with 5.0 kg Zn ha^{-1}(T_{12}) was found at par with T_{11}, T_{10}, T_{14}, T_{13} and T_9. The P uptake by seed significantly increased due to treatment T_{11} (100% RDNP with 500 kg PM enriched with 2.5 kg Zn ha^{-1}) over rest of the treatments but it remained at par with T_{12}, T_9, T_{10} and T_5 in case of seed, and straw treatment T_{12} was found at par with T_9, T_{12}, T_{13}, T_{10}, T_{14}, T_7 and T_8.

In present investigation, the Zn enriched with different organics might have favoured the better utilization of all other nutrient beside supplementation of Zn. The zinc enriched organics utilized the nutrients mainly due to its beneficial effect in mobilizing the native nutrients to increase their availability beside addition of zinc to the soil in naturally chelated form this might have provided better nutrition over longer time which causes better crop growth there by higher yield. The higher removal of N, P, and K due to zinc enriched organics along with recommended dose of nitrogen and phosphorus application could also be attributed to the priming effect of externally add nutrients to improve crop growth. The positive influence of Zn enriched different organics on N, P and K uptake has also been reported by Meena *et al.* (2015) [6] and Patel *et al.* (2010) [8].

The higher P and K uptake was due to the influence of organics and organic acid produced during decomposition of organic materials in soils resulted in mineralizing the insoluble phosphate into more soluble phosphate reported by Veeranagappa *et al.* (2010) [14].

The reduction in the content of phosphorus owing to application of zinc may be due to the antagonistic reaction between zinc and phosphorus. However, at lower zinc level increase in phosphorus content was observed. The increased concentration of zinc created hindrance in absorption and translocation of phosphorus from the roots to the above ground parts due to the formation of $Zn_3(PO_4)_2$ compounds which is unavailable to plants. Similar, results were also reported by Sharma and Lal (1990) [12] and Choudhary *et al.* (1997) [1].

Zn uptake by seed and straw

The treatment receiving 100 percent recommended dose of fertilizer along with 500 kg poultry manure ha^{-1} enriched with 5.0 kg Zn (T_{12}) recorded significantly the highest uptake of Zn by seed and straw (Table 6 and Fig 2) over rest of the treatments except treatments are T_{11}, T_{10} and T_9 in seed, Zn uptake in straw the treatment except was T_{11}. The increase in the uptake of Zn by seed due to 100 percent recommended dose of fertilizer along with 500 kg poultry manure ha^{-1}

enriched with 5.0 kg Zn (T_{12}) was higher (72.82 percent) over T_1 (100% RDNP + 500 kg ha^{-1}).

It might be due to the Zn enriched organics PM, VC, BGS and FYM caused higher utilization of Zn mainly due to its beneficial effects in mobilizing the native nutrients to increase their availability beside naturally chelated form. This might have provided better nutrition over longer time to cause better crop growth and higher yield. The higher removal of Zn by seed and straw also be attributed to the priming effect of externally added nutrients to improve crop growth hence higher content of Zn in seed and straw and also higher seed and straw yield under Zn enriched different organics application might have contributed towards higher uptake of Zn by seed and straw. The results are in accordance with those reported by Latha *et al.* (2001) [4] and Patel *et al.* (2010) [8].

Table 6: Effect of different Zn-enriched organics on N, P, K and Zn uptake by seed and straw of pearl millet.

Treatment No.	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)		Zn uptake (g/ha)	
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
T_1	55.95	27.11	13.47	13.91	16.25	62.63	109.28	72.84
T_2	60.02	32.16	17.11	16.48	18.72	66.65	129.02	78.88
T_3	61.80	34.13	16.34	15.55	19.17	67.17	139.08	83.03
T_4	59.14	30.94	14.66	15.68	17.27	66.67	115.66	77.29
T_5	64.86	33.82	18.91	16.44	20.10	71.48	133.31	80.80
T_6	57.74	30.01	14.01	15.42	16.62	65.85	110.41	76.41
T_7	63.12	36.87	18.11	17.61	19.51	70.11	139.11	81.63
T_8	64.95	37.94	17.75	16.71	20.10	71.20	152.16	85.11
T_9	73.90	42.83	21.52	20.13	22.18	78.43	166.27	89.86
T_{10}	76.60	45.11	21.16	19.00	22.65	80.30	173.92	94.47
T_{11}	79.43	48.56	22.37	21.27	23.33	81.65	176.37	103.05
T_{12}	82.88	50.13	22.17	19.81	23.98	84.23	188.86	110.61
T_{13}	65.93	40.90	19.20	19.17	20.32	77.52	153.60	91.17
T_{14}	67.04	42.05	18.50	17.69	20.59	78.96	157.20	98.31
S.Em.±	4.12	2.46	1.21	1.08	1.06	3.56	8.61	3.75
C.D. at 5%	11.94	7.13	3.60	3.14	3.06	10.32	24.94	10.88
C.V. (%)	10.70	11.20	11.81	10.74	9.12	8.44	10.21	7.44

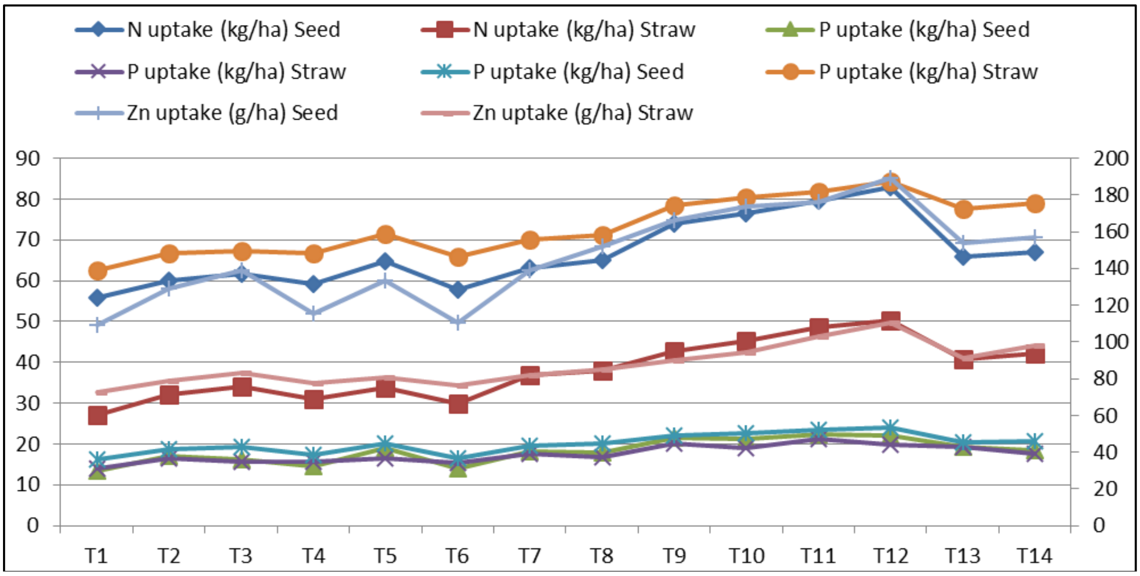

Fig 2: Effect of different Zn-enriched organics on N, P, K and Zn uptake by seed and Straw of pearl millet.

Available nutrient in soil at harvest

Organic carbon

Application of either Zn alone and its combination enriched with different organics (PM, VC, BGS and FYM) were improved organic carbon status of the soil over rest of the treatment, but the overall effect was found non-significant.

Available nitrogen

The data presented on available nitrogen content in soil did not differed significantly due to different treatments (Table 4). Application of Zn enriched organics improved the available N status in soil after harvest of the pearl millet crop as compared to straight application.

Available Phosphate

The available P_2O_5 content in soil did not differed significantly due to different Zn enriched organic application (Table 7 and fig 3.)

Available Potash

The result pertaining to available K status of soil already presented in Table 4. Indicated the application of Zn-enriched organics did not significantly variation in available K content of soil.

Table 7: Effect of different Zn-enriched organics on OC, available N, P_2O_5, K_2O and Zn in soil after harvest of pearl millet

Treatment No.	0 -15 cm soil depth				
	Organic carbon (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available Zn (g/ha)
T_1	0.229	163.10	47.94	264.34	0.347
T_2	0.229	164.77	50.33	266.63	0.377
T_3	0.231	166.13	49.55	267.91	0.402
T_4	0.230	164.23	49.23	266.72	0.360
T_5	0.227	170.00	50.45	270.24	0.363
T_6	0.218	163.67	48.74	265.98	0.353
T_7	0.256	167.73	50.38	269.58	0.387
T_8	0.252	167.67	49.85	270.74	0.430
T_9	0.248	172.13	51.15	270.71	0.407
T_{10}	0.242	172.53	50.51	271.89	0.443
T_{11}	0.240	173.77	52.40	277.01	0.430
T_{12}	0.239	174.73	51.65	277.81	0.453
T_{13}	0.235	169.77	50.69	272.16	0.417
T_{14}	0.238	170.43	49.70	273.48	0.445
S.Em.±	0.008	4.87	1.61	8.13	0.013
C.D. at 5%	NS	NS	NS	NS	0.037
C.V. (%)	6.127	5.00	5.56	5.21	5.445
Initial status	0.190	165.00	42.60	272.50	0.366

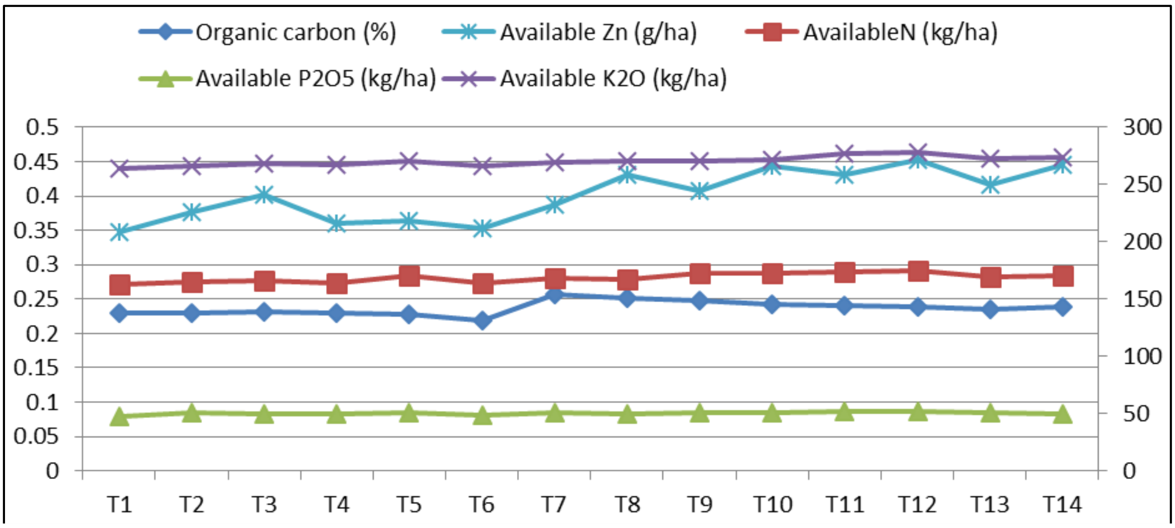

Fig 3: Effect of different Zn-enriched organics on OC, available N, P_2O_5, K_2O and Zn in Soil after harvest of pearl millet

Available Zn

The available Zn in soil after harvest of pearl millet was significantly affected by treatments as shown in table 7 and fig 3 revealed that Zn-enriched PM provide maximum amount of DTPA extractable Zn after pearl millet followed by VC and BGS. This clearly shows that the available Zn status of soil was significantly higher by the enrichment of zinc with different organics over straight application of zinc. The poultry manure used in study itself also contained appreciable quantity of Zn (165 mg kg^{-1}) its application after Zn enrichment might have helped in increasing available Zn status. The available Zn content in soil under treatment 100 percent recommended dose of fertilizer along with 500 kg poultry manure ha^{-1} enriched with 5.0 kg Zn (T_{12}) higher 30.54 percent as over T_1 (100% RDNP + 500 kg FYM ha^{-1}) Since, the soil was deficient in Zn, its supplementation in the form of enriched PM, VC, BGS and FYM application proved to be more beneficial due to protection of this nutrient from fixation by providing natural chelation in the organic complexes and to release the nutrient over longer time for crop nutrition. The positive influence of Zn-enriched organics on soil DTPA-Zn has also been reported by Latha *et al.* (2001) [4] and Patel *et al*. (2010) [10].

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