Effects of Organic Manures, Iron and Zinc enriched FYM on Nutrients Content and Uptake by Pearlmillet in Sardarkrushinagar, India

ABSTRACT

A field experiment was conducted at the Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar in India to study the effect of organic manures, iron and zinc enriched FYM on nutrients content and uptake by pearlmillet in loamy sand (*Typic Ustipsamments*) during the *kharif* season of 2022 and 2023. The pooled results indicated that application of castor cake @ 1 t ha^{-1} recorded significantly higher Nitrogen (N) and Phosphorus (P) content in both the grain and the straw and N, P, and Potassium (K) uptake by both grain and straw, while Iron (Fe) and Zinc (Zn) uptake by the straw of pearlmillet. Among different Fe and Zn supplementation, an application of 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe recorded significantly higher P content in the straw, Fe and Zn content in the grain and straw and N, P, K, Fe and Zn uptake by the grain and straw of *kharif* pearlmillet.

Key word: Pearl millet, Organic manures, Iron and Zinc, Enriched FYM, Nutrients.

1. INTRODUCTION

"Pearlmillet is commonly known as Bajri or Bajra in India. Pearlmillet (*Pennisetum glaucum* L.) is known as 'bullrush millet', originated in tropical Western Africa. India is the largest producer of pearlmillet in world. India ranks first, both in area and production of pearlmillet. In India pearlmillet is cultivated over an area of 6.70 M ha with a production of 9.62 million tonnes and the productivity is 1436 kg ha^{-1}" (Anon., 2022[a]). "Pearlmillet cultivation is dispersed mainly during the *kharif* season across the country. The major pearlmillet growing states are Rajasthan, Maharashtra, Uttar Pradesh, Gujarat and Haryana contributing 90% of the total national production. In Gujarat, pearlmillet occupies an area of 0.45 million ha and production of 1.08 million tonnes with the productivity of 2442 kg ha^{-1}" (Anon., 2022[b]). Banaskantha, Junagadh, Jamnagar, Rajkot, Mahesana, Kheda, Amreli and Kutch are the major pearlmillet growing districts of Gujarat.

The productivity of pearlmillet, which is much lesser than its production potential, vary greatly with rainfall quantity, intensity and its distribution. Hence, the research effort should be diverted to overcome the constraints that are responsible for its productivity. To bring millets into mainstream for exploiting the nutritional rich properties and promoting their cultivation, the Goverment of India has declared Year 2018 as the "Year of Millets" and the Year 2021 was declared as "International Year of Millets" by FAO Committee on Agriculture (COAG) forum.

Zinc and iron deficiencies are well documented and realizing public health issues nearly half of the world population especially in developing countries like India. Zinc and iron deficiencies are the common micronutrient deficiencies in light textured soils of North Gujarat. Which limiting both crop production and nutritional quality. Further, very low concentrations and poor bioavailability of Zn and Fe in the commonly used cereals aggravated the micronutrient deficiencies. Breeding for new cereal genotypes with high genetic capacity for grain accumulation of micronutrients is widely accepted and most sustainable solution to the problem. However, the breeding approach is a long-term process and may be affected from very low chemical solubility of Zn and Fe in soils due to high pH and low organic matter (Cakmak, 2008). Therefore, agronomy-related approaches offer short-term and complementary solutions to the Zn and Fe deficiency in crop production and human health. Soil amendments contributing to solubility of Zn and Fe in soil solution, cereal-legume intercropping systems, and soil and foliar application of micronutrient-containing fertilizers are well documented which contribute to root uptake resulted accumulation of Fe and Zn in shoot and grain of plants.

"The reports in literature indicated that the availability of micronutrients in soil can be enhanced when applied together with organics" (Bhoyar *et al.,* 1998). Mixing of inorganic salts of micronutrients with different organic manures *viz*., FYM can enhance the efficiency of micronutrients.

2. Materials and Methods

The field experiment was laid out on fixed site of plot number C-9 during *kharif* season of 2022 and 2023 at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha (Gujarat). The experimental field consisted an even topography with a gentle slope and good drainage. The soil responds well to manuring and irrigation. The soil samples were collected randomly from different spots of the experimental site from 0-15 cm depth before layout of experiment during first year (2022) and analysed for physical, chemical and biological properties of soil. The values of physico-chemical and biological properties of soil along with methodology followed are given in Table 1. The data of soil analysis indicated that the soil of the experimental field was loamy sand in texture, low in organic carbon, available nitrogen and DTPA- extractable Fe and Zn, medium in available phosphorus and potassium status. EC was normal showing that the soil was free from salinity hazard.

Experiment was carried out in split plot design, in which three organic manures was selected as main plot, whereas six treatments of Fe and Zn supplementation were taken as sub plot. Ultimately, eighteen treatment combinations involving three organic manures and six treatments of Fe and Zn supplementation were tested in this investigation.

Treatments:

Main plot: Organic manures

M_1 : FYM @ 10 t ha^{-1}

M_2 : NADEP compost @ 10 t ha^{-1}

M_3 : Castor cake @ 1 t ha^{-1}

Sub plot: Fe and Zn supplementation

F_1 : 2.5 kg Zn ha^{-1}

F_2 : 4.5 kg Fe ha^{-1}

F_3 : 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1}

F_4 : 500 kg FYM ha^{-1} enriched with 1.25 kg Zn

F_5 : 500 kg FYM ha^{-1} enriched with 2.25 kg Fe

F_6 : 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe

* Note:- After applying organic sources, remaining amount of recommended dose of nitrogen and phosphorous was counter balanced through urea and P_2O_5 respectively.

Table 1 : Physico-chemical properties of experimental soil

Sr. No.		Properties	Values at soil depth 0-15 cm 2022-23	Method employed
1.	**Physical properties**			
	(a)	Coarse sand (%)	84.32	International Pipette method (Piper, 1966)
	(b)	Silt (%)	7.28	
	(c)	Clay (%)	8.40	
	(d)	Textural class	Loamy sand	
2.	**Chemical properties**			
	(a)	Soil pH (1:2.5 soil: water ratio)	7.42	Potentiometric method (Jackson, 1973)
	(b)	Electrical Conductivity (dS m^{-1})	0.162 (Normal)	Schofield method (Jackson, 1973)
	(c)	Organic carbon (%)	0.296 (Low)	Walkley and Black's rapid titration method (Jackson, 1973)
	(d)	Available N (kg ha^{-1})	160.14 (Low)	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
	(e)	Available P_2O_5 (kg ha^{-1})	43.52 (Medium)	Olsen's method (Olsen *et al.,* 1954)
	(f)	Available K_2O (kg ha^{-1})	220.0 (Medium)	1 N ammonium acetate method (Jackson, 1973)
	(g)	**DTPA- extractable micronutrient cations**		
	1.	Fe (mg kg^{-1})	4.23 (Low)	Extraction: 0.005 M DTPA (pH 7.3) (Estimation: Atomic Absorption Spectrophotometric (Model: ELICO SL 194) (Lindsay and Norvell, 1978).
	2.	Zn (mg kg^{-1})	0.459 (Low)	
3.	**Physical properties**			
	(a)	Bulk density (Mg m^{-3})	1.413	Core method (Culley, 1993)
4.	**Biological properties (cfu /g of soil)**			

	(a)	Total bacterial count	92×10^6	Spread plate method (Sanders, 2012)

2.1 Composition of organic input

Nutrients content and total bacterial count of organic manures used in the experiment are mentioned in Table 2.

Table 2: Nutrients content and total bacterial count of organic manures

S. No.	**Organic manures**	**Years**	**Nutrients content (%)**					**Total bacterial count (10^6 cfu/g soil)**
			N	**P**	**K**	**Fe (mg kg^{-1})**	**Zn (mg kg^{-1})**	
1	FYM	2022-23	0.56	0.30	0.58	5350	88	194
		2023-24	0.59	0.32	0.62	5718	92	187
2	NADEP compost	2022-23	0.83	0.43	0.51	3950	76	178
		2023-24	0.98	0.47	0.53	4245	83	166
3	Castor cake	2022-23	4.16	1.64	1.20	79	51	142
		2023-24	4.28	1.69	1.22	84	65	136

2.2 Enrichment of FYM with iron and zinc

Looking to the widespread Fe and Zn deficiencies in many parts of state especially in North Gujarat, Fe and Zn fertilization on deficient soils is of great importance for improving productivity of such soils. The use of enriched FYM with Fe and Zn is expected to improve their efficiencies. Therefore, the locally available FYM was enriched with Fe and Zn. The Fe and Zn enriched FYM was prepared at Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The sufficient quantity of uniform FYM was used for Fe and Zn enrichment process.

The enrichment process was started 45 days before their use in *kharif* experiment on pearlmillet during both the year of experimentation *i.e.* 2022 and 2023. For the enrichment of FYM with Fe and Zn, the required amount of $FeSO_4.7H_2O$ and $ZnSO_4.7H_2O$ as per enrichment treatment *i.e.* 1.25 kg Zn ha^{-1}and 2.25 kg Fe ha^{-1} and 1.25 kg Zn ha^{-1} + 2.25 kg Fe ha^{-1} were mixed in 500 kg FYM and filled in predugged pit of 1.5' × 1.5' × 1.5' size. The moisture of FYM after mixing with $ZnSO_4$.$7H_2O$ and $FeSO_4.7H_2O$ were kept about 75 to 80 %. The starter inoculums of microorganisms in the form of cow dung slurry @ 1% was applied to boost up the microbiological activities for enrichment of natural process of composting to fix the externally added inorganic Fe and Zn into organically bound and naturally chelated form of Fe and Zn; a process called as enrichment of FYM with Fe and Zn. The initial sample of FYM was collected for analysis to know the initial status of nutrients in FYM. The pit was covered with polythene sheet and allowed for decomposition. The mixture was turned over periodically (weekly) and moisture level was maintained. The enrichment process was considered as complete after 6 weeks based on the earlier observation (Rathod, 2003).

The enriched FYM was taken out from the pits and mixed thoroughly to make the uniform enriched material. The final samples were drawn for the analysis of nutrient contents as per standard methods given in Table 1. The contents of the various nutrients *viz.*, N, P, K, Fe and Zn in Fe and Zn enriched FYM initially and after enrichment are given in Table 3 and 4. The Fe and Zn enriched FY M was applied as per treatments to pearlmillet crop.

Table 3: Nutrient content of FYM (before enrichment)

Sr. No.	Parameters	FYM	
		2022-23	2023-24
1	Nitrogen (%)	0.56	0.59
2	Phosphorus (%)	0.30	0.32
3	Potassium (%)	0.58	0.62
4	Iron (mg kg^{-1})	5350	5718
5	Zinc (mg kg^{-1})	88	92

Table 4 : Nutrient content of FYM after enrichment

Sr. No.	Treatment combinations	Years	Nutrients content				
			N	P	K	Fe (mg kg^{-1})	Zn (mg kg^{-1})
1	500 kg FYM ha^{-1} enriched with 1.25 kg Zn	2022-23	0.61	0.34	0.62	5863	172
		2023-24	0.63	0.36	0.64	6025	212
2	500 kg FYM ha^{-1} enriched with 2.25 kg Fe	2022-23	0.60	0.32	0.59	6326	109
		2023-24	0.61	0.33	0.61	6570	156
3	500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe	2022-23	0.62	0.36	0.64	6674	191
		2023-24	0.64	0.37	0.67	6836	230

2.3 Statistical analysis

The statistical analysis of the data generated was carried out through a computer software following the standard procedure as described by Cochran and Cox (1967). The variances of different sources of variation in ANOVA were tested by the 'F' test and compared with the value of Table 'F' at a 5% level of significance. S. Em. ±, critical differences (CD) and coefficient of variance (C.V. %) were also worked out. The pooled analysis of the two years data was carried out as per the procedure suggested by Cochran and Cox (1967) as the site of the experiment was fixed and randomization of the treatments was the same for both the years.

3. RESULTS AND DISCUSSION

3.1 Nutrients Content

3.1.1 Nitrogen content

3.1.1.1 Effect of organic manures

It is evidenced from the data presented in Table 5 explicit that the application of castor cake @ 1 t ha^{-1} produced significantly higher N content in pearlmillet seed (1.80, 1.82 and 1.81 %) and straw (0.817, 0.834 and 0.825 %) as compared to rest of treatments except NADEP compost @ 10 t ha^{-1} during both the years of study as well as in pooled data in straw and also found at par with NADEP compost @ 10 t ha^{-1} during both years in pearlmillet seed. Though the lowest N content in pearlmillet Seed and straw were noted under treatment FYM @ 10 t ha^{-1}.

Application of castor cake contain high nitrogen and released more amount of nitrogen in the soil by enhancing mineralization and checking downward movement of nitrogen making it more available to the growing crop which might improve nitrogen content in both the seed and straw. These findings are in close conformity with those reported by Bhutadiya *et al.* (2019) and Nisarata *et al.* (2021).

3.1.1.2 Effect of Fe and Zn supplementation

The data given in Table 5 indicated that application of Fe and Zn supplementation had no significant effect on the N content in pearlmillet Seed and straw during both the years of study and in pooled results.

3.1.2 Phosphorus content

3.1.2.1 Effect of organic manures

It is evident from the data presented in Table 6 explicit that P content in pearlmillet seed and straw were significantly affected due to different organics manures. An application of castor cake @ 1 t ha^{-1} registered significantly the higher P content in pearlmillet seed and straw as compared to rest of the treatments and it was also found at par with the treatment NADEP compost @ 10 t ha^{-1} during first year and in pooled results of study in the seed.

Higher availability of phosphorus in the soil during growth period increases absorption of phosphorous under application of castor cake. Absorption of nutrients by plant roots and their transportation towards foliage and later on translocation in the seed by various metabolic activities resulted in higher phosphorus content in seed and straw. Similar results were found by Solanki *et al.* (2022) and Nisarata *et al.* (2021).

3.1.2.2 Effect of Fe and Zn supplementation

The data given in Table 6 indicated that application of Fe and Zn supplementation had no significant effect on the P content in pearlmillet seed and straw during both the years of study and in seed pooled results, but significantly the higher P content straw found due to the application of 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe pearlmillet over rest of treatments in pooled result but it was remained at par with 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 500 kg FYM ha^{-1} enriched with 2.25 kg Fe.

The increased in P concentration in straw might be attributed to favorable influence of organic acids released in mobilization of native soil to make P readily available to roots during crop growing seasons. The results of present investigation are in close agreements with the findings of Pawar *et al.* (2015) in sorghum.

3.1.3 Potassium content

3.1.3.1 Effect of organic manures

It is evident from the data presented in Table 7 revealed that the potassium content in seed of pearlmillet did not differ significantly due to the application of different organic manures during both the individual years and as well as in pooled analysis in straw, but significantly the highest potassium content in pearlmillet seed was recorded under the treatment castor cake @ 1 t ha^{-1} in pooled analysis only as compared to rest of the treatments.

Higher availability of potassium in the soil during growth period increases absorption of potassium under application of castor cake. Absorption of nutrients by plant roots and their transportation towards foliage and later on translocation in the seed by various metabolic activities resulted in higher potassium content in seed. The results of present investigation are in close agreements with the findings of Bhutadiya *et al.* (2019).

3.1.3.2 Effect of Fe and Zn supplementation

A perusal of data presented in Table 7 revealed that different treatments of Fe and Zn supplementation did not exert any significant influences on the K content in seed and straw of pearlmillet during both the individual years and in pooled results.

3.1.4 Iron content

3.1.4.1 Effect of organic manures

It is evident from the data presented in Table 8 explicit that the iron content in seed significantly affected due to different organics manures. An application of FYM @ 10 t ha^{-1} found significantly higher Fe content in pearlmillet seed as compared to rest of the treatments and it was remained at par with the treatment NADEP compost @ 10 t ha^{-1} during both the year and in pooled results in seed. Straw of pearlmillet did not significantly affect by the application of different organic manures but numerically the higher Fe content was recorded under the treatment of FYM @ 10 t ha^{-1} in straw during both the years of study as well as in pooled analysis.

The significant increase in nutrient content in plant ascribed to the beneficial role of FYM in mineralization of native nutrients in soil through added fertilizers in addition of its own nutrient content which enhanced the available nutrients pool of soil. The favourable conditions for microbial as well as chemical activities due to addition of FYM augmented the mineralization of nutrients and ultimately the available nutrient pool of the soil. similar result was found by Jat *et al*. (2013).

3.1.4.2 Effect of Fe and Zn supplementation

A perusal of data presented in Table 8 revealed that iron content in seed and straw of pearlmillet influenced significantly under the influence of various Fe and Zn supplementation during both the years as well as in pooled analysis. Among all the Fe and Zn supplementation, an application of 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe produced significantly the higher iron content in Seed and straw of pearlmillet over rest of treatments during both the years and in pooled result but it was remained at par with 500 kg FYM ha^{-1} enriched with 2.25 kg Fe, 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1} in straw and 4.5 kg Fe ha^{-1} in seed only.

The improved zinc and iron content in seed and straw could be attributed to the formation of stable organometallic complexes with organic matter, especially during the enrichment process to last for longer time and release the nutrients in such a way that the nutrients protected from fixation and made available to the plant root system throughout the crop growth. These results are in the line of those reported by Mansuri *et al.* (2019) in pearlmillet and Maganur and Kubsad (2020) in sorghum.

3.1.4.3 Interaction effect

The interaction between organic manures and Fe and Zn supplementation was found significant with respect to iron content by seed during first years and pooled results of study (Table 9). The treatment combination FYM @ 10 t ha^{-1} + 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe recorded significantly higher iron content compared to rest of the treatment combinations during first year and pooled results. Significantly the lowest iron content (60.74 mg kg^{-1}) by Seed was registered under the treatment combination of castor cake @ 1 t ha^{-1} + 2.5 kg Zn ha^{-1}.

It might be due to addition of FYM add organic matter to the soil which helps in mobilizing the native nutrients besides the incorporation of nutrients present in it. Further, enrichment of Fe and Zn with FYM increased the total Fe and Zn content in it. It is believed that enrichment techniques fix the nutrient in natural chelation form which is expected to growing crop over a longer time which might have helped to provide balance nutrition of Fe and Zn to pearlmillet crop that increased Fe and Zn content in Seed. Thus, increase in Fe and Zn content in Seed might be due to synergistic effect of FYM and enriched FYM with Fe and Zn. Similar results were recorded by Vishwakarma *et al.* (2023) in wheat and Ahmad *et al.* (2012) in rice.

3.1.5 Zinc content

3.1.5.1 Effect of organic manures

It is evidenced from the data presented in Table 10 explicit that the application of FYM @ 10 t ha^{-1} produced significantly higher Zn content in pearlmillet Seed (44.11, 45.70 and 44.91 mg kg^{-1}) compared to rest of treatments except NADEP compost @ 10 t ha^{-1} during both the years of study and zinc content in straw of pearlmillet did not significantly affect by the application of different organic manures. but numerically higher value was recorded under the treatment FYM @ 10 t ha^{-1} of during both the years of study as well as in pooled data.

The considerable increase in Zn content in Seed might be due to FYM could be attributed to fact that it's beneficial effects in mineralization of native as well as its own nutrient content by creating favourable condition for microbial as well as chemical activities which enhanced the available Zn content in soil and there by resulted into higher content of Zn in the seed. Similar results were found by Jat *et al*. (2013).

3.1.5.2 Effect of Fe and Zn supplementation

A perusal of the data presented in Table 10 revealed that zinc content in seed and straw of pearlmillet influenced significantly under the influence of various Fe and Zn supplementation during both the years as well as in pooled analysis. Among all the Fe and Zn supplementation, an application of 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe produced significantly the highest zinc content in seed and straw of pearlmillet over rest of treatments during both the years and in pooled result but it was remained at par with 500 kg FYM ha^{-1} enriched with 1.25 kg Zn, 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1} in the seed and straw and also with 2.5 kg Zn ha^{-1} in the seed at both years and in straw year first only.

The observed significant increase in Fe and Zn concentration in seed and straw due to application of Fe and Zn enriched FYM might be due to fact that soil of experiment plot was deficient in available iron and zinc and its application after enrichment of FYM had beneficial effect on mobilizing native Fe and Zn nutrients to increase their availability in soil and also addition of Fe and Zn to the soil in naturally chelated form to provide better nutrition over longer time that caused higher utilization of Fe and Zn by seed and straw. The results of present investigation are in close agreements with the findings of Solanki *et al*. (2020) in wheat.

3.1.5.3 Interaction effect

The data presented in Table 11 revealed that treatment combination FYM @ 10 t ha^{-1} + 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe found significantly higher zinc content in the seed compared to rest of treatment combinations during year 2023 and in a pooled results. Significantly the lowest zinc content in the seed was registered under treatment combination of castor cake @ 1 t ha^{-1} + 4.5 kg Fe ha^{-1}.

Combined application of FYM and Zn showed that the decomposition of organic matter resulted in the production of low molecular organic acid like humic and fluvic acids, acetic, formic, oxalic, lactic, propionic, malic, citric, and aconitic acids. FYM have a better structure and may contain humic acid, growth hormones and high microbial population resulted into increased CO_2 concentration in soil arising from microbial activity and decomposition of native organic matter. The CO_2 in contact with water forms carbonic acid which creates acidity. Addition of FYM increase the organic acids in the soil which react with the sparingly soluble salts already present converting them to soluble salts. The results of present investigation are in close agreements with the findings of Pathak *et al.* (2017) in pearlmillet-wheat cropping system.

3.2 Nutrients uptake

3.2.1 Nitrogen uptake

3.2.1.1 Effect of organic manures

An examination of the data presented in Table 12 explicit that the nitrogen uptake by seed and straw of pearlmillet significantly affected by the application of different organic manures during both the individual years as well as in pooled analysis. An application of castor cake @ 1 t ha^{-1} registered significantly the higher nitrogen uptake 43.41, 45.44 and 44.43 kg ha^{-1} by Seed and 44.11, 45.87 and 44.99 kg ha^{-1} by straw during 2022, 2023 and in pooled results only as compared to rest of the treatments except NADEP compost @ 10 t ha^{-1} during 2022 in pearlmillet seed and during 2023 in the straw only.

The reason behind the highest uptake of N due to the application of castor cake @ 1 t ha^{-1} is directly related with the yield and N content in Seed. This treatment castor cake @ 1 t ha^{-1} received maximum yield and N content in Seed which would have resulted in generally higher N uptake with this treatment. Similar outcome also observed by Bhutadiya *et al.* (2019).

3.2.1.2 Effect of Fe and Zn supplementation

It is evident from the data presented in Table 12 explicit that nitrogen uptake by the seed and the straw of pearlmillet was significantly affected due to different Fe and Zn supplementation. An application of 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe recorded significantly higher nitrogen uptake by Seed and straw during both the individual years as well as in pooled data as compared to rest of the treatments but it was remained at par with 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and in seed during both years and in pooled analysis and with 500 kg FYM ha^{-1} enriched with 2.25 kg Fe during both the years in seed and in straw second year only.

A significant increase in uptake of N by seed and straw of pearlmillet as observed in present study under Fe and Zn enriched organics might be the outcome of increased these nutrients (N) in both the seed and straw as well as increased the yield of seed and straw. Similar effects have also been observed by Sridevi *et al.* (2010) in rice and Veerangappa *et al.* (2011) in rice.

3.2.2 Phosphorus uptake

3.2.2.1 Effect of organic manures

An examination of data presented in Table 13 explicit that the phosphorus uptake by seed and straw of pearlmillet affected significantly by the application of different organic manures during both the years of study as well as in pooled results. An application of castor cake @ 1 t ha^{-1} registered significantly the highest phosphorus uptake by seed and straw of pearlmillet as compared to rest of treatments during both the years of study and in pooled analysis, but in Seed during both years it was found at par with treatment NADEP compost @ 10 t ha^{-1}.

The higher uptake of the phosphorus by pearlmillet seed and straw might be due to more availability of phosphorus by balanced N-P fertilization which resulted into higher concentration of phosphorus in both seed and straw and uptake of phosphorus by pearlmillet. The increased uptake by pearlmillet might be due to improvement in soil physical, chemical and biological health through application of organic manures. Similar results were found by Nisarata *et al.* (2021).

3.2.2.2 Effect of Fe and Zn supplementation

Phosphorus uptake by pearlmillet seed and straw were significantly influenced by different Fe and Zn supplementation during both years of study as well as in pooled analysis (Table 13). Significantly higher phosphorus uptake by pearlmillet seed and straw were recorded under the treatment 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe during 2022, 2023 and in pooled analysis over rest of treatments and it was found at par with treatment 500 kg FYM ha^{-1} enriched with 1.25 kg Zn during both years and in pooled results in both the seed and straw and with treatment 500 kg FYM ha^{-1} enriched with 2.25 kg Fe during both years in seed and in straw second year only.

In present investigation, the Fe and Zn enriched FYM might have favour the better utilization of all other nutrients besides supplementation of Fe and Zn. The higher uptake of P might be due attributed to the favourable influence of organic acid produced during the decomposition of organic materials in soils resulted in mineralizing the insoluble phosphate into more soluble phosphates in soil to make P readily available to roots during crop growing season. Similar results were found in Sorghum by Kumar *et al.* (2020), Solanki *et al*. (2021) in wheat and Krupashree and Rao (2022) in foxtail millet.

3.2.3 Potassium uptake

3.2.3.1 Effect of organic manures

It is evident from the data presented in Table 14 revealed that the potassium uptake by seed and straw of pearlmillet were significantly affected by the application of different organic manures. An application of castor cake @ 1 t ha^{-1} recorded significantly the highest potassium uptake by seed during both the years of study and in pooled analysis. However, it was at par with the application of NADEP compost @ 10 t ha^{-1} during both the years and in pooled results.

Castor cake is a natural source of potassium and its application ensures an optimal balance of both macronutrients, facilitating enhanced potassium uptake by the pearlmillet. This balanced nutrient supply promotes better nutrient absorption and utilization, leading to improved growth, development and yield of the crop. Similar outcome also observed by Bhutadiya *et al.* (2019).

3.2.3.2 Effect of Fe and Zn supplementation

Potassium uptake by Seed of pearlmillet was significantly influenced by different Fe and Zn supplementation during both the years of study as well as in pooled results (Table 14). Significantly the higher potassium uptake by pearlmillet seed were recorded under the treatment 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe during 2022, 2023 and in pooled analysis as compared to rest of the treatments. But in case of pearlmillet straw K uptake did not differ significantly under the influence of various Fe and Zn supplementation during year 2023 and significantly higher K uptake by straw in year 2022 and pooled was recorded under the treatment 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe and remained at par with the treatment 500 kg FYM ha^{-1} enriched with 2.25 kg Fe.

A significant increase in uptake of K by both the seed and straw of pearlmillet as observed in present study under Fe and Zn enriched organics might be the outcome of increased these nutrients (K) in seed and straw as well as increased the yield of seed and straw. These results are in the line of those reported by Sridevi *et al.* (2010) in rice and Mansuri *et al.* (2019) in pearl millet.

3.2.3.3 Interaction effect

The data presented in Table 15 revealed that treatment combination of castor cake @ 1 t ha^{-1} + 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe produced significantly highest K uptake by seed of *kharif* pearlmillet compared to rest of the treatment combinations during in pooled results. Significantly the lowest K uptake by Seed of *kharif* pearlmillet was registered under treatment combination of FYM @ 10 t ha^{-1} + 4.5 kg Fe ha^{-1}.

Castor cake is a natural source of potassium application ensures an optimal balance of both macronutrients, facilitating enhanced potassium uptake by the pearlmillet. This balanced nutrient supply promotes better nutrient absorption and utilization, leading to improved growth, development and yield of the crop. The higher uptake of K might be due attributed to the favourable influence of organic acid produced during the decomposition of organic materials in soils resulted in mineralizing nutrients in soil to make K readily available to roots during crop growing season. Similar effects have also been recorded by Pathak *et al.* (2017) pearlmillet-wheat cropping system.

3.2.4 Iron uptake

3.2.4.1 Effect of organic manures

A perusal of data presented in Table 16 revealed that different organic manures did not exert any significant influences on iron uptake by seed of *kharif* pearlmillet during individual years as well as in pooled results but in case of iron uptake by straw was found significantly higher with application of castor cake @ 1 t ha^{-1} (719.5 and 725.5) and it was remained at par with NADEP compost @ 10 t ha^{-1} during the year 2022 and in pooled results.

A considerable increase in uptake of Fe and Zn by seed and straw due to castor cake as observed in present study might be due to the outcome of increased these nutrients (Fe) in seed and straw as well as increase yield of seed and straw. Similar outcome also observed by Jat *et al*. (2013).

3.2.4.2 Effect of Fe and Zn supplementation

An examination of data presented in Table 16 revealed that significantly the higher iron uptake by seed and straw of pearlmillet were recorded under the treatment 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe during 2022, 2023 and in pooled results over rest of the treatments but it was remained at par with 500 kg FYM ha^{-1} enriched with 2.25 kg Fe during both the individual years.

The higher uptake of iron and zinc by seed and straw was mainly attributed to higher dry matter production, higher seed and straw yield. The higher uptake of iron and zinc by seed and straw might be also due to the faster decomposition of organic and further, enrichment of nutrients with organics prevents them from leaching, fixation and other losses. This increases the available cationic micronutrient concentration in soil solution thereby increased the uptake of these micronutrients by seed and straw. Similar effects have also been recorded by Krupashree and Rao (2022) in foxtail millet and Rathod *et al*. (2012) in wheat-maize (fodder) cropping sequence.

3.2.4.3 Interaction effect

The interaction between organic manures and Fe and Zn supplementation was found significant with respect to iron uptake by seed during first years and pooled results of study (Table 17). The combined application of castor cake @ 1 t ha^{-1} + 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe recorded significantly higher iron uptake compared to rest of the treatment combinations during first year and pooled of result. Significantly the lowest iron uptake (131.1 and 141.4 g ha^{-1}) by seed was registered under the treatment combination of FYM @ 10 t ha^{-1} + 4.5 kg Fe ha^{-1}.

The higher application of FYM coupled with high rate of Fe enrichment caused higher utilization of Fe by the crop. The Zn and Fe enriched FYM caused higher utilization of micronutrients mainly due to its beneficial effects in mobilizing the native nutrients to increase their availability besides addition of Zn and Fe to the soil in naturally chelated form. This might have provided better nutrition over longer time to cause better crop growth and thereby higher yields. The higher uptake of Zn and Fe due to Zn and Fe enriched FYM along with organic manures application could also be attributed to the priming effect of externally added nutrients to improve crop growth. The increase in yield could be a reason for higher uptake of the nutrients due to balanced fertilization. Similar outcome also observed by Meena *et al.* (2006) in sorghum.

3.2.5 Zinc uptake

3.2.5.1 Effect of organic manures

It is evident from the data presented in Table 18 revealed that the zinc uptake in seed and straw of pearlmillet did not differ significantly due to the application of different organic manures during both the individual years and in straw as well as in pooled result but significantly the higher zinc uptake by pearlmillet straw was recorded under the treatment castor cake @ 1 t ha^{-1} in pooled results as compared to rest of the treatments. The considerable increase in uptake of Zn by straw due to castor cake as observed in present study might be due to the outcome of increased Seed and straw yield. Similar outcome also observed by Jat *et al*. (2013).

3.2.5.2 Effect of Fe and Zn supplementation

The data presented in Table 18 indicated that significantly the higher zinc uptake by pearlmillet Seed and straw were recorded under the treatment of 500 kg FYM ha^{-1} enriched with

1.25 kg Zn and 2.25 kg Fe but it was remained at par with treatment 500 kg FYM ha^{-1} enriched with 1.25 kg Zn during both the individual year as well as in pooled results.

This can be attributed to the increased dry matter production associated with increased supply of zinc, which would have helped in the absorption of N from the soil by providing more binding sites. The enhanced uptake could also be attributed to the involvement of zinc in enzymatic reactions as well as the formation of protein-Zn complex. The increase in zinc uptake with the advancement of crop growth stages could be attributed to the increased dry matter production and better foraging ability of the roots with increasing root biomass. Similar results were found by Veerangappa *et al.* (2011) in rice, Sridevi *et al.* (2010) in rice and Rathod *et al.* (2012) in wheat-maize (fodder) cropping sequence.

3.2.5.3 Interaction effect

The data presented in Table 19 revealed that treatment combination of castor cake @ 1 t ha^{-1} + 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe produced significantly higher Zn uptake by seed of *kharif* pearlmillet compared to rest of the treatment combinations during in pooled results. Significantly the lowest Zn uptake by seed of *kharif* pearlmillet was registered under treatment combination of FYM @ 10 t ha^{-1} + 4.5 kg Fe ha^{-1}.

It might be due to the effect of Zn enriched 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. The higher uptake 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 yield under Zn enriched different organics application might have contributed towards higher uptake of Zn by seed and straw. Similar result was found by Meena *et al.* (2015).

Table 5: Nitrogen content in pearlmillet as influenced by organic manures and Fe and Zn supplementation

Treatments	N content (%)					
	Seed			Straw		
	2022	2023	Pooled	2022	2023	Pooled
Main plot: Organic manures (M)						
M_1: FYM @ 10 t ha^{-1}	1.70	1.72	1.71	0.689	0.704	0.696
M_2: NADEP compost @ 10 t ha^{-1}	1.73	1.77	1.75	0.801	0.810	0.805
M_3: Castor cake @ 1 t ha^{-1}	1.80	1.82	1.81	0.817	0.834	0.825
S. Em. ±	0.021	0.021	0.015	0.010	0.009	0.007
C. D. (P= 0.05)	0.072	0.072	0.045	0.036	0.033	0.021

CV%	5.86	5.77	5.81	6.57	5.88	6.23
Sub plot: Fe and Zn supplementation (F)						
F_1: 2.5 kg Zn ha^{-1}	1.73	1.75	1.74	0.762	0.776	0.769
F_2: 4.5 kg Fe ha^{-1}	1.72	1.75	1.73	0.753	0.765	0.759
F_3: 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1}	1.74	1.76	1.75	0.767	0.780	0.773
F_4: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn	1.76	1.78	1.77	0.777	0.790	0.784
F_5: 500 kg FYM ha^{-1} enriched with 2.25 kg Fe	1.76	1.77	1.76	0.770	0.784	0.777
F_6: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe	1.77	1.80	1.78	0.783	0.799	0.791
Mean	1.75	1.77	1.76	0.769	0.782	0.776
S. Em. ±	0.024	0.026	0.018	0.010	0.012	0.008
C. D. (P= 0.05)	NS	NS	NS	NS	NS	NS
Year						
S. Em. ±	-	-	0.011	-	-	0.005
C. D. (P= 0.05)	-	-	NS	-	-	NS
Y × T						
S. Em. ±	-	-	0.044	-	-	0.020
C. D. (P= 0.05)	-	-	NS	-	-	NS
Significant interactions (s)	-	-	-	-	-	-
CV%	4.84	5.08	4.96	4.58	5.49	5.06

Table 6: Phosphorus content in pearl millet as influenced by organic manures and Fe and Zn supplementation

Treatments	P content (%)					
	Seed			Straw		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
Main plot: Organic manures (M)						
M_1: FYM @ 10 t ha^{-1}	0.324	0.335	0.330	0.165	0.168	0.166
M_2: NADEP compost @ 10 t ha^{-1}	0.340	0.345	0.343	0.173	0.176	0.175
M_3: Castor cake @ 1 t ha^{-1}	0.350	0.353	0.351	0.180	0.184	0.182
S. Em. ±	0.004	0.004	0.003	0.002	0.002	0.001
C. D. (P= 0.05)	0.014	NS	0.009	0.007	0.007	0.005
CV%	5.79	6.06	5.93	5.69	5.99	5.85
Sub plot: Fe and Zn supplementation (F)						
F_1: 2.5 kg Zn ha^{-1}	0.336	0.343	0.340	0.171	0.174	0.172
F_2: 4.5 kg Fe ha^{-1}	0.332	0.336	0.334	0.168	0.172	0.170
F_3: 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1}	0.338	0.345	0.341	0.172	0.175	0.173
F_4: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn	0.340	0.347	0.344	0.176	0.178	0.177
F_5: 500 kg FYM ha^{-1} enriched with 2.25 kg Fe	0.338	0.346	0.342	0.174	0.176	0.175

F_6: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe	0.342	0.350	0.346	0.177	0.180	0.179
Mean	0.338	0.345	0.341	0.173	0.176	0.174
S. Em. ±	0.005	0.004	0.003	0.002	0.003	0.002
C. D. (P= 0.05)	NS	NS	NS	NS	NS	0.005
Year						
S. Em. ±	-	-	0.002	-	-	0.001
C. D. (P= 0.05)	-	-	NS	-	-	NS
Y × T						
S. Em. ±	-	-	0.008	-	-	0.004
C. D. (P= 0.05)	-	-	NS	-	-	NS
Significant interactions (s)	-	-	-	-	-	-
CV%	5.10	4.52	4.81	4.71	4.97	4.84

Table 7: Potassium content in pearl millet as influenced by organic manures and Fe and Zn supplementation

Treatments	**K content (%)**					
	Seed			**Straw**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
Main plot: Organic manures (M)						
M_1: FYM @ 10 t ha^{-1}	0.585	0.596	0.590	1.61	1.65	1.63
M_2: NADEP compost @ 10 t ha^{-1}	0.602	0.614	0.608	1.64	1.66	1.65
M_3: Castor cake @ 1 t ha^{-1}	0.622	0.631	0.627	1.68	1.68	1.68
S. Em. ±	0.008	0.008	0.006	0.019	0.020	0.014
C. D. (P= 0.05)	NS	NS	0.018	NS	NS	NS
CV%	6.79	6.77	6.78	5.80	5.80	5.80
Sub plot: Fe and Zn supplementation (F)						
F_1: 2.5 kg Zn ha^{-1}	0.599	0.606	0.602	1.63	1.66	1.65
F_2: 4.5 kg Fe ha^{-1}	0.595	0.598	0.597	1.62	1.65	1.64
F_3: 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1}	0.600	0.612	0.606	1.64	1.67	1.65
F_4: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn	0.605	0.624	0.615	1.65	1.67	1.66
F_5: 500 kg FYM ha^{-1} enriched with 2.25 kg Fe	0.604	0.620	0.612	1.65	1.67	1.66
F_6: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe	0.616	0.623	0.619	1.66	1.68	1.67
Mean	0.603	0.614	0.609	1.64	1.67	1.66
S. Em. ±	0.008	0.008	0.006	0.017	0.018	0.012
C. D. (P= 0.05)	NS	NS	NS	NS	NS	NS
Year						
S. Em. ±	-	-	0.004	-	-	0.010
C. D. (P = 0.05)	-	-	NS	-	-	NS
Y × T						

S. Em. ±	-	-	0.014	-	-	0.030
C. D. (P = 0.05)	-	-	NS	-	-	NS
Significant interactions (s)	-	-	-	-	-	-
CV%	4.49	4.44	4.47	3.56	3.73	3.65

Table 8: Iron content in pearl millet as influenced by organic manures and Fe and Zn supplementation

Treatments	**Fe content (mg kg^{-1})**					
	Seed			**Straw**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
Main plot: Organic manures (M)						
M_1: FYM @ 10 t ha^{-1}	74.63	76.21	75.42	135.24	139.80	137.52
M_2: NADEP compost @ 10 t ha^{-1}	73.02	74.48	73.75	134.19	136.93	135.56
M_3: Castor cake @ 1 t ha^{-1}	69.84	70.71	70.27	132.93	133.10	133.02
S. Em. ±	0.848	0.897	0.617	1.637	1.606	1.147
C. D. (P= 0.05)	2.93	3.10	1.90	NS	NS	NS
CV%	5.73	5.95	5.85	5.98	5.76	5.87
Sub plot: Fe and Zn supplementation (F)						
F_1: 2.5 kg Zn ha^{-1}	69.81	70.53	70.17	126.02	129.94	127.98
F_2: 4.5 kg Fe ha^{-1}	72.61	73.87	73.24	128.36	131.90	130.13
F_3: 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1}	73.63	74.05	73.84	137.70	140.90	139.30
F_4: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn	70.95	72.85	71.90	126.75	129.66	128.20
F_5: 500 kg FYM ha^{-1} enriched with 2.25 kg Fe	73.91	74.68	74.30	142.93	142.52	142.73
F_6: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe	74.05	76.84	75.45	142.99	144.72	143.85
Mean	72.49	73.80	73.15	134.13	136.61	135.37
S. Em. ±	1.032	1.222	0.800	1.917	1.827	1.324
C. D. (P= 0.05)	2.94	3.48	2.25	5.461	5.204	3.720
Year						
S. Em. ±	-	-	0.467	-	-	0.867
C. D. (P= 0.05)	-	-	NS	-	-	NS
Y × T						
S. Em. ±	-	-	1.959	-	-	3.243
C. D. (P= 0.05)	-	-	NS	-	-	NS
Significant interactions (s)	-	M × F	M × F	-	-	-
CV%	4.93	5.74	5.36	4.95	4.63	5.87

Table 9: Interaction effect of organic manures and Fe and Zn supplementation on Fe content (mg kg^{-1}) in Seed of pearlmillet

M × F	2022					
	F_1	F_2	F_3	F_4	F_5	F_6
M_1	74.86	75.98	73.37	74.83	79.02	79.21
M_2	75.98	74.82	75.19	74.89	70.83	75.21
M_3	60.74	70.82	73.57	68.82	74.21	76.11
S. Em. ±	2.117					
C. D. (P= 0.05)	6.03					
Pooled						
M_1	73.84	75.41	74.31	74.34	77.23	77.38
M_2	73.69	73.74	74.44	73.65	72.36	74.64
M_3	62.99	70.58	72.76	69.37	73.31	74.32
S. Em. ±	1.385					
C. D. (P= 0.05)	3.89					

Table 10: Zinc content in pearlmillet as influenced by organic manures and Fe and Zn supplementation

Treatments	Zn content (mg kg^{-1})					
	Seed			Straw		
	2022	2023	Pooled	2022	2023	Pooled
Main plot: Organic manures (M)						
M_1: FYM @ 10 t ha^{-1}	44.11	45.70	44.91	36.94	37.24	37.09
M_2: NADEP compost @ 10 t ha^{-1}	43.39	44.04	43.72	36.59	36.91	36.75
M_3: Castor cake @ 1 t ha^{-1}	41.71	41.85	41.78	35.07	36.80	35.93
S. Em. ±	0.497	0.531	0.364	0.447	0.431	0.311
C. D. (P= 0.05)	1.72	1.84	1.12	NS	NS	NS
CV%	5.65	5.93	5.79	6.05	5.71	5.88
Sub plot: Fe and Zn supplementation (F)						
F_1: 2.5 kg Zn ha^{-1}	42.92	43.72	43.32	36.03	36.40	36.21
F_2: 4.5 kg Fe ha^{-1}	40.80	42.11	41.46	35.36	35.84	35.60
F_3: 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1}	43.65	44.38	44.01	36.28	37.05	36.66
F_4: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn	44.10	44.58	44.34	36.98	38.02	37.50
F_5: 500 kg FYM ha^{-1} enriched with 2.25 kg Fe	42.56	43.31	42.93	35.37	36.35	35.86
F_6: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe	44.40	45.09	44.75	37.20	38.24	37.72
Mean	43.07	43.87	43.47	36.20	36.98	36.59

S. Em. ±	0.566	0.593	0.410	0.454	0.455	0.321
C. D. (P= 0.05)	1.61	1.69	1.15	1.293	1.295	0.903
Year						
S. Em. ±	-	-	0.275	-	-	0.235
C. D. (P= 0.05)	-	-	NS	-	-	NS
Y × T						
S. Em. ±	-	-	1.003	-	-	0.787
C. D. (P= 0.05)	-	-	NS	-	-	NS
Significant interaction (s)	-	M × F	M × F	-	-	-
CV%	4.55	4.68	5.79	4.35	4.26	4.30

Table 11: Interaction effect of organic manures and Fe and Zn supplementation on Zn content (mg kg^{-1}) in Seed of pearlmillet

M × F	**2023**					
	F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**
M_1	46.15	43.54	46.62	47.67	42.29	47.96
M_2	43.23	43.82	43.28	44.00	45.69	44.19
M_3	41.77	38.98	43.23	42.08	41.94	43.12
S. Em. ±	1.026					
C. D. (P= 0.05)	2.92					
Pooled						
M_1	44.92	43.22	45.58	46.24	42.90	46.58
M_2	43.30	42.93	43.56	44.06	44.29	44.16
M_3	41.74	38.22	42.90	42.74	41.60	43.50
S. Em. ±	0.710					
C. D. (P= 0.05)	1.99					

Table 12: N uptake by pearlmillet as influenced by organic manures and Fe and Zn supplementation

Treatments	**N uptake (kg ha^{-1})**					
	Seed			**Straw**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
Main plot: Organic manures (M)						
M_1: FYM @ 10 t ha^{-1}	36.46	37.48	36.97	32.55	34.27	33.41
M_2: NADEP compost @ 10 t ha^{-1}	39.74	41.88	40.81	40.15	42.18	41.16
M_3: Castor cake @ 1 t ha^{-1}	43.41	45.44	44.43	44.11	45.87	44.99
S. Em. ±	1.09	1.12	0.78	1.066	1.195	0.801
C. D. (P= 0.05)	3.76	3.89	2.41	3.69	4.14	2.47
CV%	13.34	13.24	13.29	13.41	14.36	13.92
Sub plot: Fe and Zn supplementation (F)						
F_1: 2.5 kg Zn ha^{-1}	38.97	39.85	39.41	37.68	39.49	38.59
F_2: 4.5 kg Fe ha^{-1}	36.62	39.26	37.94	36.85	38.59	37.72

F_3: 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1}	39.50	40.93	40.21	37.95	39.84	38.89
F_4: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn	41.04	43.04	42.04	39.76	42.27	41.01
F_5: 500 kg FYM ha^{-1} enriched with 2.25 kg Fe	40.49	42.30	41.40	39.06	41.41	40.23
F_6: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe	42.60	44.23	43.41	42.33	43.04	42.69
Mean	39.87	41.60	40.74	38.94	40.77	39.86
S. Em. ±	0.912	0.997	0.675	1.044	1.052	0.741
C. D. (P= 0.05)	2.60	2.84	1.90	2.97	3.00	2.08
Year						
S. Em. ±	-	-	0.591	-	-	0.605
C. D. (P= 0.05)	-	-	NS	-	-	NS
Y × T						
S. Em. ±	-	-	1.654	-	-	1.815
C. D. (P= 0.05)	-	-	NS	-	-	NS
Significant interactions (s)	-	-	-	-	-	-
CV%	7.92	8.30	8.12	9.29	8.93	13.92

Table 13: P uptake by pearlmillet as influenced by organic manures and Fe and Zn supplementation

Treatments	P uptake (kg ha^{-1})					
	Seed			Straw		
	2022	2023	Pooled	2022	2023	Pooled
Main plot: Organic manures (M)						
M_1: FYM @ 10 t ha^{-1}	6.93	7.35	7.14	7.77	8.16	7.96
M_2: NADEP compost @ 10 t ha^{-1}	7.79	8.16	7.98	8.69	9.18	8.93
M_3: Castor cake @ 1 t ha^{-1}	8.46	8.82	8.64	9.75	10.11	9.93
S. Em. ±	0.226	0.251	0.169	0.149	0.224	0.135
C. D. (P= 0.05)	0.78	0.87	0.52	0.52	0.78	0.41
CV%	14.34	15.15	14.78	8.35	12.01	10.43
Sub plot: Fe and Zn supplementation (F)						
F_1: 2.5 kg Zn ha^{-1}	7.58	7.82	7.70	8.44	8.83	8.64
F_2: 4.5 kg Fe ha^{-1}	7.08	7.57	7.33	8.17	8.67	8.42
F_3: 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1}	7.70	7.80	7.85	8.51	8.92	8.71
F_4: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn	7.92	8.37	8.15	8.96	9.52	9.24
F_5: 500 kg FYM ha^{-1} enriched with 2.25 kg Fe	7.80	8.27	8.04	8.81	9.30	9.05
F_6: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe	8.26	8.62	8.44	9.53	9.67	9.60
Mean	7.72	8.08	7.92	8.74	9.15	8.94
S. Em. ±	0.189	0.200	0.138	0.216	0.224	0.156

C. D. (P= 0.05)	0.54	0.57	0.39	0.61	0.64	0.44
Year						
S. Em. ±	-	-	0.128	-	-	0.102
C. D. (P= 0.05)	-	-	NS	-	-	0.314
Y × T						
S. Em. ±	-	-	0.337	-	-	0.381
C. D. (P= 0.05)	-	-	NS	-	-	NS
Significant interactions(s)	-	-	-	-	-	-
CV%	8.46	8.56	8.51	8.56	8.49	10.43

Table 14: K uptake by pearlmillet as influenced by organic manures and Fe and Zn supplementation

Treatments	**K uptake (kg ha^{-1})**					
	Seed			**Straw**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
Main plot: Organic manures (M)						
M_1: FYM @ 10 t ha^{-1}	12.52	13.04	12.78	75.91	80.21	78.06
M_2: NADEP compost @ 10 t ha^{-1}	13.83	14.56	14.19	82.45	86.66	84.55
M_3: Castor cake @ 1 t ha^{-1}	15.03	15.73	15.38	90.78	92.74	91.76
S. Em. ±	0.497	0.415	0.324	2.561	2.711	1.865
C. D. (P= 0.05)	1.72	1.44	1.00	8.86	9.38	5.74
CV%	17.63	14.08	15.88	15.11	15.35	15.24
Sub plot: Fe and Zn supplementation (F)						
F_1: 2.5 kg Zn ha^{-1}	13.49	13.80	13.65	80.68	84.04	82.36
F_2: 4.5 kg Fe ha^{-1}	12.72	13.48	13.10	79.25	82.91	81.08
F_3: 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1}	13.67	14.20	13.94	81.36	84.79	83.07
F_4: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn	14.11	15.02	14.57	84.26	89.13	86.69
F_5: 500 kg FYM ha^{-1} enriched with 2.25 kg Fe	13.94	14.81	14.37	83.51	87.90	85.70
F_6: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe	14.85	15.34	15.09	89.24	90.43	89.83
Mean	13.80	14.44	14.12	83.05	86.53	84.79
S. Em. ±	0.304	0.331	0.224	2.124	2.083	1.487
C. D. (P= 0.05)	0.86	0.94	0.63	6.05	NS	4.18
Year						
S. Em. ±	-	-	0.245	-	-	1.409
C. D. (P= 0.05)	-	-	NS	-	-	NS
Y × T						
S. Em. ±	-	-	0.550	-	-	3.644
C. D. (P= 0.05)	-	-	NS	-	-	NS
Significant interactions (s)	-	-	M × F	-	-	-
CV%	7.62	7.93	15.88	8.86	8.34	15.24

Table 15: Interaction effect of organic manures and Fe and Zn supplementation on K uptake (kg ha^{-1}) in Seed of pearlmillet

M × F	Pooled					
	F_1	F_2	F_3	F_4	F_5	F_6
M_1	12.15	10.53	12.60	13.79	13.46	14.17
M_2	14.07	13.99	14.27	14.20	14.38	14.26
M_3	14.71	14.78	14.94	15.71	15.29	16.85
S. Em. ±	0.389					
C. D. (P= 0.05)	1.09					

Table 16: Fe uptake by pearlmillet as influenced by organic manures and Fe and Zn supplementation

Treatments	Fe uptake (g ha^{-1})					
	Seed			Straw		
	2022	2023	Pooled	2022	2023	Pooled
Main plot: Organic manures (M)						
M_1: FYM @ 10 t ha^{-1}	159.7	166.8	163.2	638.0	680.9	659.4
M_2: NADEP compost @ 10 t ha^{-1}	167.4	176.4	171.9	672.4	713.5	692.9
M_3: Castor cake @ 1 t ha^{-1}	168.7	176.7	172.7	719.5	731.6	725.5
S. Em. ±	4.61	4.40	3.19	15.24	18.26	11.89
C. D. (P= 0.05)	NS	NS	NS	52.7	NS	36.7
CV%	13.67	12.45	13.05	11.04	12.63	11.90
Sub plot: Fe and Zn supplementation (F)						
F_1: 2.5 kg Zn ha^{-1}	156.6	159.8	158.2	621.4	657.1	639.2
F_2: 4.5 kg Fe ha^{-1}	153.9	165.4	159.6	625.2	660.7	643.0
F_3: 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1}	167.6	171.6	169.6	681.2	717.1	699.1
F_4: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn	165.0	175.6	170.3	645.4	690.4	667.9
F_5: 500 kg FYM ha^{-1} enriched with 2.25 kg Fe	170.2	178.4	174.3	720.3	749.4	734.8
F_6: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe	178.2	189.2	183.7	766.3	777.1	771.7
Mean	165.3	173.3	169.3	676.6	708.6	692.6
S. Em. ±	3.57	5.18	3.15	17.53	16.73	12.12
C. D. (P= 0.05)	10.2	14.8	8.8	49.9	47.7	34.0
Year						
S. Em. ±	-	-	2.410	-	-	8.992
C. D. (P= 0.05)	-	-	7.43	-	-	27.71
Y × T						
S. Em. ±	-	-	7.715	-	-	29.68

C. D. (P= 0.05)	-	-	NS	-	-	NS
Significant interactions (s)	M ×F	-	M × F	-	-	-
CV%	7.49	10.37	9.12	8.97	8.18	8.57

Table 17: Interaction effect of organic manures and Fe and Zn supplementation on Fe uptake (g ha^{-1}) by seed of pearlmillet

M × F	**2022**					
	F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**
M_1	154.4	131.1	163.3	167.6	169.9	171.5
M_2	162.3	165.1	169.0	166.3	168.9	172.9
M_3	153.1	165.6	170.4	161.0	171.8	190.1
S. Em. ±	3.57					
C. D. (P= 0.05)	10.2					
Pooled						
M_1	155.3	141.4	160.5	169.3	175.2	177.8
M_2	169.5	169.5	174.1	172.9	169.0	176.5
M_3	149.9	168.0	174.1	168.7	178.7	196.8
S. Em. ±	3.15					
C. D. (P= 0.05)	8.8					

Table 18: Zinc uptake by pearlmillet as influenced by organic manures and Fe and Zn supplementation

Treatments	**Zn uptake (g ha^{-1})**					
	Seed			**Straw**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
Main plot: Organic manures (M)						
M_1: FYM @ 10 t ha^{-1}	94.41	100.00	97.21	173.92	181.12	177.52
M_2: NADEP compost @ 10 t ha^{-1}	99.68	104.19	101.93	183.37	192.38	187.87
M_3: Castor cake @ 1 t ha^{-1}	100.81	104.41	102.61	189.84	202.28	196.06
S. Em. ±	2.597	2.444	1.783	4.338	6.165	3.769
C. D. (P= 0.05)	NS	NS	NS	NS	NS	11.61
CV%	12.94	11.64	12.28	11.65	15.74	13.95
Sub plot: Fe and Zn supplementation (F)						
F_1: 2.5 kg Zn ha^{-1}	96.66	99.24	97.95	177.60	184.36	180.98
F_2: 4.5 kg Fe ha^{-1}	86.25	94.20	90.23	171.69	179.47	175.58
F_3: 2.5 kg Zn ha^{-1} and 4.5 kg Fe ha^{-1}	99.31	102.62	100.97	179.14	188.92	184.03
F_4: 500 kg FYM ha^{-1} enriched with 1.25 kg Zn	102.61	107.21	104.91	188.19	202.63	195.41
F_5: 500 kg FYM ha^{-1} enriched with 2.25 kg Fe	98.05	103.16	100.60	178.42	191.40	184.91
F_6: 500 kg FYM ha^{-1} enriched with	106.92	110.75	108.83	199.23	204.77	202.00

1.25 kg Zn and 2.25 kg Fe						
Mean	98.30	102.86	100.58	182.38	191.93	187.15
S. Em. ±	2.305	2.340	1.642	4.479	3.565	2.862
C. D. (P= 0.05)	6.56	6.66	4.61	12.76	10.16	8.04
Year						
S. Em. ±	-	-	1.348	-	-	2.849
C. D. (P= 0.05)	-	-	4.153	-	-	8.779
Y × T						
S. Em. ±	-	-	4.023	-	-	7.011
C. D. (P= 0.05)	-	-	NS	-	-	NS
Significant interactions (s)	-	-	M × F	-	-	-
CV%	8.12	7.88	8.00	8.51	6.44	13.95

Table 19: Interaction effect of organic manures and Fe and Zn supplementation on Zn uptake (g ha^{-1}) by Seed of pearlmillet

M × F	**Pooled**					
	F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**
M_1	94.42	81.02	98.38	105.29	96.98	107.14
M_2	99.96	98.74	101.91	103.23	103.47	104.28
M_3	99.47	90.93	102.60	106.22	101.36	115.07
S. Em. ±	2.844					
C. D. (P= 0.05)	7.99					

4. CONCLUSION

On the basis of two years experimental findings, it is concluded that application of castor cake @ 1 t ha^{-1} recorded significantly higher Nitrogen (N) and Phosphorus (P) content in both the grain and the straw and N, P, and Potassium (K) uptake by both grain and straw, while Iron (Fe) and Zinc (Zn) uptake by the straw of pearlmillet. Among different Fe and Zn supplementation, an application of 500 kg FYM ha^{-1} enriched with 1.25 kg Zn and 2.25 kg Fe recorded significantly higher P content in the straw, Fe and Zn content in the grain and straw and N, P, K, Fe and Zn uptake by the grain and straw of *kharif* pearlmillet.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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