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Effect of fly ash in combination with farm yard manure and vermicompost on nutrient content and uptake in rice

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Abstract

The study "Effect of Fly Ash in Combination with farm yard manure and Vermicompost on nutrient content and uptake in rice" was conducted at Krishi Vigyan Kendra, Janjgir-Champa, Chhattisgarh during kharif 2022 and 2023. Using a Randomized Block Design with 16 treatments across 3 replications, we evaluated various combinations of fly ash, farm yard manure, and vermicompost for their impact on nutrient uptake and nutrient content in rice. The soil was clay loam, low in nitrogen and phosphorus, with adequate potassium and slightly acidic pH. The highest nutrient uptake was observed with Fly Ash @ 30 t/ha + 100% RDN + Vermicompost @ 2.5 t/ha (T_{13}), showing superior results for nitrogen, phosphorus, potassium, and micronutrients compared to other treatments, with the lowest uptake under Fly Ash @ 20 t/ha (T_6).

Keywords: Fly ash, farm yard manure, vermicompost

1. Introduction

Rice, a staple food for one-third of the world's population, is the most important cereal crop globally and occupies about one-fifth of the total cereal land area. India ranks as the second-largest producer and consumer of rice, with Chhattisgarh often referred to as the 'Rice Bowl of India' due to its significant rice cultivation. In 2022-23, Chhattisgarh had a rice-growing area of 3,791 thousand hectares, producing 7,161.2 thousand tonnes with a productivity of 1,889 kg/ha (Anonymous I). Fly ash, a by-product of coal combustion in Thermal Power Stations (TPS), consists of amorphous ferro-aluminosilicate minerals. In 2022-2023, Chhattisgarh's 29 thermal power plants produced 34.822 million tons of fly ash, with 77.12% utilized annually. Previous studies show that combining 75% of the general recommended dose (GRD) of fertilizers with fly ash and farm yard manure (FYM) increases soil nutrients like phosphorus, potassium, and zinc, and improves organic carbon storage in degraded lands. Given the large quantities of fly ash produced and the state's promotion of organic amendments like FYM and vermicompost, this study aims to investigate the effects of fly ash, both alone and in combination with FYM and vermicompost, on nutrient content and uptake in rice.

2. Methodology

2.1 Site of Experimental field: The study was conducted on an Inceptisol at Krishi Vigyan Kendra, Jarve (cha), Janjgir-Champa, Chhattisgarh, located 154 km from Raipur at an altitude of 294.4 m above sea level. Janjgir-Champa lies between 21°06′N to 22°04′N latitude and 82°03′E to 83°02′E longitude.

2.2 Experimental Layout: The variety 'MTU1156' was grown with 20×10 cm spacing in a randomized block design with 16 treatments and 3 replications.

2.3 Observation recorded

2.3.1 Plant analysis

2.3.1.1. Nitrogen content: Nitrogen (%) content was determined using the salt mixture method (Chapman and Pratte, 1961) with a 0.50 g plant sample digested with K_2SO_4, $CuSO_4.5H_2O$, and H_2SO_4 at 400 °C, then distilled using an automatic KEL plus system.

2.3.1.2. Total Phosphorus and Potassium Content

Phosphorus content of plant samples (Grain and straw) was determined by vanadomolybdo-phosphoric acid yellow color complex method as described by Jackson (1967). An aliquot of 10 ml was taken, 10 ml of vanado-molybdate yellow reagent was added and volume was made up to 50 ml. after 30 minutes color intensity was measured by spectrophotometer at wavelength 420 nm.

Phosphorus (%): Measured using the vanadomolybdo-phosphoric acid method (Jackson, 1967) with spectrophotometry at 420 nm.

Potassium (%): Potassium content was determined by flame photometer as described by Chapman and Pratt (1961).

2.3.1.3 Total Micronutrients (Fe, Mn, Zn, Cu) (mg kg⁻¹)

One gram oven dried plant sample (grain and straw) and fly ash was digested with 10 ml of acid mixture (HNO_3 and HCL in 9:4 ratio) and final volume was made using 100 ml with deionized water. Total concentrations of zinc, copper, iron and manganese were analyzed by atomic absorption spectrophotometer.

2.3.1.4 Nutrient (kg ha⁻¹) and Micronutrient (g ha⁻¹) Uptake

Nutrient uptake = Concentration (%) × Yield (seed + straw) (q ha⁻¹)

3. Result and discussion

3.1 Nutrient Content and Uptake by Grain & Straw

3.1.1 Nitrogen Content in Grain (%): Nitrogen content ranged from 0.91 to 1.20% across years. Table 1. and fig. 1. show that treatment T8 (Fly ash @ 40 t ha⁻¹) had the highest nitrogen content, while T13 (Fly ash @ 30 t ha⁻¹ + 100% RDN + Vermicompost @ 2.5 t ha⁻¹) had the lowest.

3.1.2 Phosphorus Content in Grain (%)

Phosphorus content ranged from 0.21 to 0.40%. T8 (Fly ash @ 40 t ha⁻¹) showed the highest phosphorus content, and T13 (Fly ash @ 30 t ha⁻¹ + 100% RDN + Vermicompost @ 2.5 t ha⁻¹) had the lowest.

3.1.3. Potassium Content in Grain (%)

Potassium content ranged from 0.21 to 0.44%. T8 (Fly ash @ 40 t ha⁻¹) recorded the highest potassium content, while T1 (Fly ash @ 30 t ha⁻¹ + 100% RDN + Vermicompost @ 2.5 t ha⁻¹) had the lowest.

Table 1: Effect of fly ash in combination of farm yard manure and vermicompost on Nutrient content in grain

	Treatments	Nutrient content in grain (%)								
		Nitrogen			Phosphorus			Potassium		
		2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1	Farmers practices (N:P: K - 75:45:30 kg ha^{-1} + 1.5 t ha^{-1} Farm Yard Manure)	1.05	1.04	1.05	0.30	0.29	0.30	0.30	0.29	0.30
T_2	50% RDN (N:P: K - 50:30:20 kg ha^{-1})	1.09	1.09	1.09	0.31	0.31	0.31	0.32	0.34	0.33
T_3	Farm Yard Manure @ 5 t ha^{-1}	1.12	1.13	1.13	0.32	0.32	0.32	0.33	0.36	0.35
T_4	Vermicompost @ 2.5 t ha^{-1}	1.12	1.13	1.13	0.32	0.33	0.33	0.35	0.36	0.36
T_5	100% RDN (N:P: K - 100:60:40 kg ha^{-1})	1.00	1.00	1.00	0.27	0.27	0.27	0.26	0.25	0.26
T_6	Fly ash @ 20 t ha^{-1}	1.15	1.16	1.16	0.35	0.37	0.36	0.38	0.38	0.38
T_7	Fly ash @ 30 t ha^{-1}	1.17	1.17	1.17	0.36	0.38	0.37	0.40	0.42	0.41
T_8	Fly ash @ 40 t ha^{-1}	1.19	1.20	1.20	0.38	0.40	0.39	0.43	0.44	0.44
T_9	Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	0.95	0.95	0.95	0.24	0.23	0.24	0.23	0.23	0.23
T_{10}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	0.96	0.95	0.96	0.22	0.22	0.22	0.22	0.21	0.22
T_{11}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	0.95	0.95	0.95	0.25	0.25	0.25	0.24	0.23	0.24
T_{12}	Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	0.97	0.96	0.97	0.24	0.23	0.24	0.23	0.23	0.23
T_{13}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	0.91	0.90	0.91	0.21	0.20	0.21	0.21	0.20	0.21
T_{14}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	0.93	0.92	0.93	0.22	0.21	0.22	0.22	0.21	0.22
T_{15}	50% RDN + Farm Yard Manure @ 5 t ha^{-1}	1.03	1.02	1.03	0.29	0.28	0.29	0.28	0.27	0.28
T_{16}	50% RDN + Vermicompost @ 2.5 t ha^{-1}	1.04	1.03	1.04	0.29	0.28	0.29	0.28	0.27	0.28
	SEm±	0.08	0.01	0.05	0.00	0.01	0.01	0.01	0.01	0.01
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

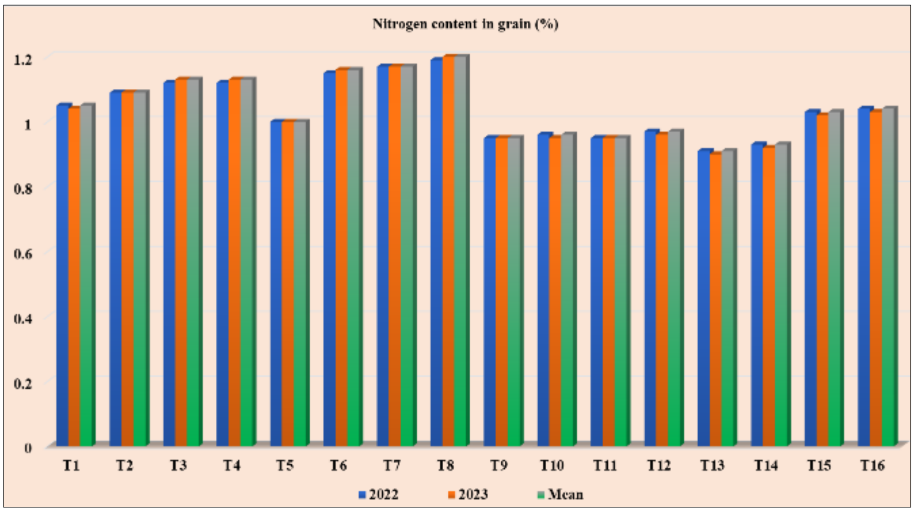

Fig 1: Effect of fly ash in combination of farm yard manure and vermicompost on nitrogen content in grain

3.1.4 Nitrogen Content in Straw (%)
Nitrogen content ranged from 0.37 to 0.47%. T8 (Fly ash @ 40 t ha^{-1}) had the highest nitrogen content, while T13 (Fly ash @ 30 t ha^{-1} + 100% RDN + Vermicompost @

3.1.5 Phosphorus Content in Straw (%)
Phosphorus content ranged from 0.37 to 0.47%. T8 (Fly ash @ 40 t ha^{-1}) showed the highest phosphorus content, and T13 (Fly ash @ 30 t ha^{-1} + 100% RDN + Vermicompost @ 2.5 t ha^{-1}) had the lowest.

3.1.6 Potassium Content in Straw (%)
Potassium content ranged from 0.37 to 0.47%. T8 (Fly ash @ 40 t ha^{-1}) had the highest potassium content, while T13 (Fly ash @ 30 t ha^{-1} + 100% RDN + Vermicompost @ 2.5 t ha^{-1}) had the lowest.

3.1.7 Nitrogen Uptake by Grain and Straw (kg ha^{-1})
The nitrogen uptake in grain and straw was found significant due to application of fly ash with combination of farm yard manure, vermicompost and inorganic fertilizers. The data relevant to nitrogen uptake in grain and straw has been tabulated in table 2. and fig. 2. From the table. 2 it is clearly indicated that treatment T_{13} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) recorded highest nitrogen uptake in grain (49.61, 49.77 & 49.69 kg ha^{-1}) among all the treatments where fly ash used in combination of with farm yard manure, vermicompost and inorganic fertilizers during both the year of experiment and mean basis, respectively. While, the lowest nitrogen uptake in grain (38.22, 35.81 & 36.02 kg ha^{-1}) was recorded in T_6 (Fly ash @ 20 t ha^{-1}) during both the years of experimentation and on a mean basis, respectively.
Similarly, the higher nitrogen uptake in straw (24.19, 24.23 & 24.21 kg ha^{-1}) was recorded in T_{13} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) compared to other treatments. While, the lowest nitrogen uptake in straw (17.92, 17.97 & 17.95 kg ha^{-1}) was recorded in T_6 (Fly ash @ 20 t ha^{-1}) during both the years of experimentation and on a mean basis, respectively.
Table 2. and fig 2. showed that the total nitrogen uptake (grain & straw) was found significant due to application of fly ash with farm yard manure, vermicompost and inorganic fertilizers. The data revealed that the treatment T_{13} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) was recorded highest total nitrogen uptake (73.81, 74.01 & 73.91 kg ha^{-1}) among all the treatments. While, the lowest total nitrogen uptake (54.13, 53.78 & 53.96 kg ha^{-1}) was recorded in treatment T_6 (Fly ash @ 20 t ha^{-1}) during both the years of experimentation and on a mean basis, respectively.
This might be due to complementary effect on nitrogen availability to rice through its growth. Which could also be attributed to good soil physical environment, thereby better root prolification due to fly ash addition. Singh and Singh (1986) observed increased nitrogen uptake by rice plant due to application of fly ash. Similar results were also reported by Jambagi *et al.* (1995) [3], Selvakumari *et al.* (2000) [7] and Ramteke (2016) [4].

3.1.8 Phosphorus Uptake in Grain and Straw (kg ha^{-1})
The results presented in table 3. and fig. 3. showed that the treatment of fly ash with and without farm yard manure, vermicompost & inorganic fertilizers was not found significant phosphorus uptake in grain and straw. The experiment resulted that treatment T_{13} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) was recorded highest phosphorus uptake in grain (11.65, 11.75 & 11.70 kg ha^{-1}) followed by T_{14} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}). While, the lowest phosphorus uptake in grain (10.08, 9.64 & 9.86 kg ha^{-1}) was recorded in treatment T_6 (Fly ash @ 20 t ha^{-1}) during both the years of experimentation and on a mean basis, respectively.
In the same way table 3. and fig 3. showed that the higher phosphorus uptake in straw (2.31, 2.51 & 2.41 kg ha^{-1}) was recorded in treatment T_{13} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}). While, the lowest phosphorus uptake in straw (1.75, 1.66 & 1.71 kg ha^{-1}) was recorded in treatment T_6 (Fly ash @ 20 t ha^{-1}) during both the years of experimentation and on a mean basis, respectively.
Similarly, the total phosphorus uptake (grain & straw) was not found significant due to application of fly ash with and without farm yard manure, vermicompost & inorganic fertilizer. The data revealed that the treatment T_{13} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) was recorded highest total phosphorus uptake (13.96, 14.26 & 14.11 kg ha^{-1}) among all the treatments. While, the lowest total phosphorus uptake (11.83, 11.30 & 11.57 kg ha^{-1}) was recorded in treatment T_6 (Fly ash @ 20 t ha^{-1}) during both the years of experimentation and on a mean basis, respectively. Similar findings were also reported by Selvakumari *et al.* (2000) [7] and Warambhe *et al.* (1993) [9].

Table 2: Effect of fly ash in combination of farm yard manure and vermicompost on Nitrogen uptake (Grain, Straw & Total) by Rice crop

	Treatments	Nitrogen uptake (kg ha^{-1})								
		Grain			Straw			Total		
		2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1	Farmers practices (N:P: K - 75:45:30 kg ha^{-1} + 1.5 t ha^{-1} Farm Yard Manure)	47.58	47.30	47.44	23.13	23.46	23.30	70.71	70.76	70.74
T_2	50% RDN (N:P: K - 50:30:20 kg ha^{-1})	45.07	43.90	44.49	20.77	20.88	20.83	65.84	64.78	65.31
T_3	Farm Yard Manure @ 5 t ha^{-1}	42.00	41.11	41.56	19.60	18.95	19.28	61.60	60.06	60.83
T_4	Vermicompost @ 2.5 t ha^{-1}	41.57	41.33	41.45	19.77	19.28	19.53	61.33	60.62	60.98
T_5	100% RDN (N:P: K - 100:60:40 kg ha^{-1})	49.30	48.81	49.06	24.05	23.08	23.57	73.35	71.89	72.62
T_6	Fly ash @ 20 t ha^{-1}	36.22	35.81	36.02	17.92	17.97	17.95	54.13	53.78	53.96
T_7	Fly ash @ 30 t ha^{-1}	38.32	36.58	37.45	18.18	18.41	18.30	56.50	55.00	55.75
T_8	Fly ash @ 40 t ha^{-1}	38.99	37.70	38.35	18.64	18.88	18.76	57.63	56.58	57.11
T_9	Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	48.82	48.64	48.73	24.14	23.81	23.98	72.96	72.45	72.71
T_{10}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	48.85	48.42	48.64	23.82	23.65	23.74	72.67	72.07	72.37
T_{11}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	48.67	48.70	48.69	24.31	23.93	24.12	72.97	72.63	72.80
T_{12}	Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	48.63	48.25	48.44	23.77	23.53	23.65	72.40	71.78	72.09
T_{13}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	49.61	49.77	49.69	24.19	24.23	24.21	73.81	74.01	73.91
T_{14}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	49.08	49.33	49.21	24.09	23.93	24.01	73.18	73.26	73.22
T_{15}	50% RDN + Farm Yard Manure @ 5 t ha^{-1}	46.65	46.04	46.35	22.44	21.62	22.03	69.08	67.66	68.37
T_{16}	50% RDN + Vermicompost @ 2.5 t ha^{-1}	47.78	47.11	47.45	22.55	21.80	22.18	70.33	68.91	69.62
	SEm±	1.38	1.43	1.40	0.53	0.48	0.50	1.68	1.67	1.68
	CD (P=0.05)	3.99	4.14	4.20	1.55	1.39	1.47	4.86	4.82	4.84

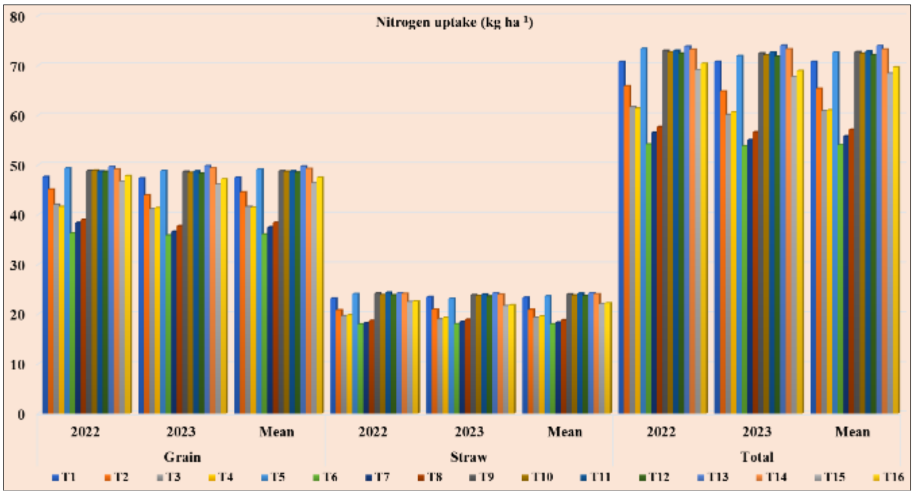

Fig 2: Effect of fly ash in combination of farm yard manure and vermicompost on nitrogen (kg ha-1) uptake (grain, Straw & Total) by rice

Table 3: Effect of fly ash in combination of farm yard manure and vermicompost on Phosphorus uptake (grain, Straw & Total) by Rice crop

	Treatments	Phosphorus uptake (kg ha^{-1})								
		Grain			Straw			Total		
		2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1	Farmers practices (N:P: K - 75:45:30 kg ha^{-1} + 1.5 t ha^{-1} Farm Yard Manure)	10.69	10.62	10.66	1.97	2.03	2.00	12.66	12.65	12.66
T_2	50% RDN (N:P: K - 50:30:20 kg ha^{-1})	10.37	10.34	10.36	1.91	1.89	1.90	12.28	12.23	12.26
T_3	Farm Yard Manure @ 5 t ha^{-1}	10.10	10.04	10.07	1.79	1.73	1.76	11.89	11.77	11.83
T_4	Vermicompost @ 2.5 t ha^{-1}	10.31	10.25	10.28	1.79	1.7	1.75	12.10	11.95	12.03
T_5	100% RDN (N:P: K - 100:60:40 kg ha^{-1})	11.30	11.35	11.33	2.03	2.09	2.06	13.33	13.44	13.39
T_6	Fly ash @ 20 t ha^{-1}	10.08	9.64	9.86	1.75	1.66	1.71	11.83	11.30	11.57
T_7	Fly ash @ 30 t ha^{-1}	10.13	9.89	10.01	1.76	1.69	1.73	11.89	11.58	11.74
T_8	Fly ash @ 40 t ha^{-1}	10.17	10.03	10.10	1.78	1.71	1.75	11.95	11.74	11.85
T_9	Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	11.39	11.54	11.47	2.07	2.21	2.14	13.46	13.75	13.61
T_{10}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	11.59	11.68	11.64	2.18	2.35	2.27	13.77	14.03	13.90
T_{11}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	11.39	11.48	11.44	2.05	2.16	2.11	13.44	13.64	13.54
T_{12}	Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	11.41	11.63	11.52	2.11	2.27	2.19	13.52	13.90	13.71
T_{13}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	11.65	11.75	11.70	2.31	2.51	2.41	13.96	14.26	14.11
T_{14}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	11.60	11.67	11.64	2.22	2.48	2.35	13.82	14.15	13.99
T_{15}	50% RDN + Farm Yard Manure @ 5 t ha^{-1}	10.71	10.65	10.68	1.95	1.89	1.92	12.66	12.54	12.60
T_{16}	50% RDN + Vermicompost @ 2.5 t ha^{-1}	10.86	11.71	11.29	1.93	1.87	1.90	12.79	13.58	13.19
	SEm±	0.36	0.40	0.38	0.24	0.21	0.23	0.57	0.66	0.62
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

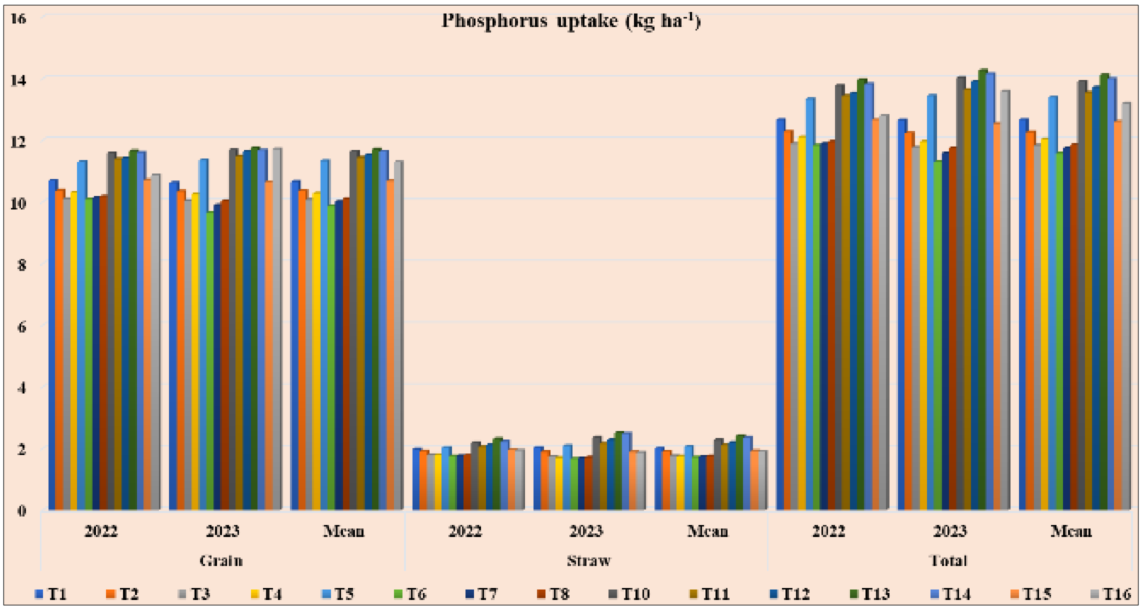

Fig 3: Effect of fly ash in combination of farm yard manure and vermicompost on phosphorus uptake (kg ha^{-1}) by rice

3.1.9 Potassium Uptake in Grain and Straw (kg ha^{-1})

The results presented in table 4. and fig. 4. showed that the potassium uptake in grain and straw was found significant due to application of fly ash with and without farm yard manure, vermicompost & inorganic fertilizer. Treatment T_{13} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) was recorded highest potassium uptake in grain (14.31, 14.02 & 14, 17 kg ha^{-1}) among all the treatments. While, the lowest potassium uptake in grain (11.99, 11.90 & 11.95 kg ha^{-1}) was recorded in treatment T_6 (Fly ash @ 20 t ha^{-1}) during both the years of experimentation and on a mean basis, respectively.

Similarly, the higher potassium uptake in straw (86.41, 87.60 & 87.01 kg ha^{-1}) was recorded in treatment T_{13} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) while, the lowest potassium uptake in straw (65.07, 65.60 & 65.34 kg ha^{-1}) was recorded in treatment T_6 (Fly ash @ 20 t ha^{-1}) during both the years of experimentation and on a mean basis, respectively.

The data revealed that the treatment T_{13} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) was recorded highest total potassium uptake (100.71, 100.62 & 100.17 kg ha^{-1}) among all the treatments. While, the lowest total potassium uptake (77.05, 77.50 & 77.28 kg ha-1) was recorded in treatment T6 (Fly ash @ 20 t ha-1) during both the years of experimentation and on a mean basis, respectively. Selvakumari *et al.* (2000) [7] also showed higher content and uptake of nutrients by rice Fly-ash @ 30 t ha-1 was applied along with chemical fertilizers and compost.

Table 4: Effect of fly ash in combination of farm yard manure and vermicompost on Potassium uptake (grain, Straw & Total) by Rice crop

	Treatments	Potassium uptake (kg ha^{-1})								
		Grain			Straw			Total		
		2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1	Farmers practices (N:P: K - 75:45:30 kg ha^{-1} + 1.5 t ha^{-1} Farm Yard Manure)	13.55	13.94	13.75	82.63	83.13	82.88	96.18	97.08	96.63
T_2	50% RDN (N:P: K - 50:30:20 kg ha^{-1})	13.41	13.15	13.28	73.13	73.38	73.26	86.54	86.54	86.54
T_3	Farm Yard Manure @ 5 t ha^{-1}	12.33	12.21	12.27	69.97	67.36	68.67	82.30	79.56	80.93
T_4	Vermicompost @ 2.5 t ha^{-1}	13.02	12.80	12.91	71.06	69.25	70.16	84.09	82.04	83.07
T_5	100% RDN (N:P: K - 100:60:40 kg ha^{-1})	13.89	13.37	13.63	83.26	86.63	84.95	97.15	100.00	98.58
T_6	Fly ash @ 20 t ha^{-1}	11.99	11.90	11.95	65.07	65.60	65.34	77.05	77.50	77.28
T_7	Fly ash @ 30 t ha^{-1}	12.96	12.37	12.67	67.88	67.62	67.75	80.84	80.00	80.42
T_8	Fly ash @ 40 t ha^{-1}	13.37	12.88	13.13	68.39	68.63	68.51	81.75	81.51	81.63
T_9	Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	14.17	13.61	13.89	84.73	86.34	85.54	98.90	99.95	99.43
T_{10}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	14.16	13.71	13.94	84.72	85.78	85.25	98.89	99.49	99.19
T_{11}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	14.08	13.54	13.81	85.94	86.21	86.08	100.02	99.75	99.89
T_{12}	Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	14.04	13.56	13.80	85.23	86.14	85.69	99.27	99.70	99.49
T_{13}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	14.31	14.02	14.17	86.41	87.60	87.01	100.71	101.62	101.17
T_{14}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	14.28	13.97	14.13	85.46	86.59	86.03	99.74	100.56	100.15
T_{15}	50% RDN + Farm Yard Manure @ 5 t ha^{-1}	12.99	13.43	13.21	79.25	77.74	78.50	92.24	91.17	91.71
T_{16}	50% RDN + Vermicompost @ 2.5 t ha^{-1}	13.17	13.59	13.38	81.26	79.60	80.43	94.43	93.19	93.81
	SEm±	0.45	0.41	0.43	1.90	1.65	1.77	2.18	1.86	2.02
	CD (P=0.05)	1.31	1.18	1.24	5.49	4.78	5.13	6.31	5.40	5.86

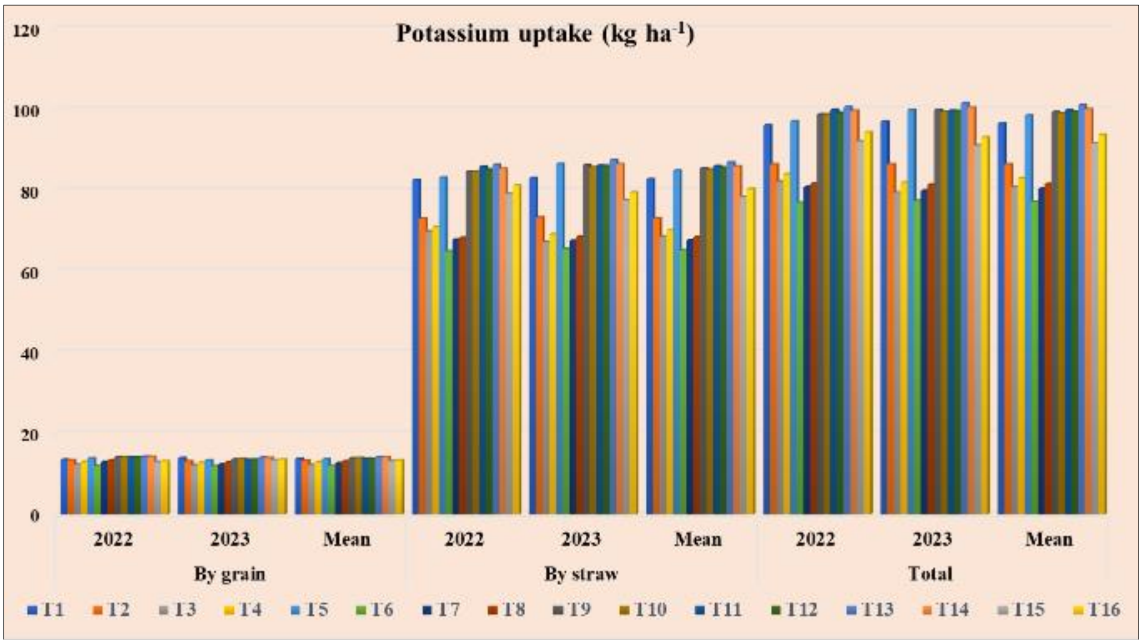

Fig 4: Effect of fly ash in combination of farm yard manure and vermicompost on potassium uptake (kg ha-1) by rice

3.2 Micronutrient Content and Uptake by Grain and Straw

3.2.1 Micronutrient Content in Grain (mg kg⁻¹)

Fe, Mn, Zn, and Cu content in grain was not significantly affected by fly ash with organic and inorganic fertilizers.

3.2.2 Micronutrient Content in Straw (mg kg⁻¹)

Fe, Mn, Zn, and Cu content in straw was not significantly affected by fly ash with organic and inorganic fertilizers.

3.3.3 Micronutrient Uptake (Fe, Mn, Zn, Cu) by Grain and Straw (g ha⁻¹)

Fe, Mn, and Zn uptake were significantly higher in T13 (Fly ash @ 30 t ha^{-1} + 100% RDN + Vermicompost @ 2.5 t ha^{-1}) compared to T6 (Fly ash @ 20 t ha^{-1}), while Cu uptake was not significantly different. T13 was on par with several other treatments.

3.3.3.1 Iron (Fe) uptake by grain and straw (g ha^{-1})

The results on iron uptake by grain and straw as significantly influenced by treatments is presented in table 5. and fig. 5. It ranged between 439.72 to 686.93, 432.67 to 694.69 & 436.20 to 690.81 g ha^{-1} during year 2022, 2023 and mean basis respectively. The maximum iron uptake was found in treatments T_{13} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) where it was minimum in treatments T_6 (Fly ash @ 20 t ha^{-1}) during both the year of experimentations and on mean basis. The treatment T_{13} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) at par with treatment T_5 (100 RDN), T_9 (Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{10} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{11} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{12} (Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) and T_{14} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) during both the year of experimentations and on mean basis.

Similarly, the significantly highest iron uptake in straw (471.31, 480.93 & 476.12 g ha^{-1}) was recorded in treatment T_{13} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) which was statistically at par with T_5 (100 RDN), T_9 (Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{10} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{11} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{12} (Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) and T_{14} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) while, the lowest iron uptake in straw (309.09, 313.75 & 311.42 g ha^{-1}) was recorded in treatment T_6 (Fly ash @ 20 t ha^{-1}) during both the years (2022, 2023) of experimentation and on a mean basis, respectively.

The data revealed that the treatment T_{13} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) was recorded highest total iron uptake (1158.24, 1175.62 & 1166.93 g ha^{-1}) among all the treatments which was at parr with T_5 (100 RDN), T_9 (Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{10} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{11} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{12} (Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}), and T_{14} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) while, the lowest total iron uptake (748.80, 746.42 & 747.61 g ha^{-1}) was recorded in treatment T_6 (Fly ash @ 20 t ha^{-1}) during both the years of experimentation and on a mean basis, respectively.

Table 5: Effect of fly ash in combination of farm yard manure and vermicompost on iron uptake (g ha^{-1}) by rice

	Treatments	Iron uptake (g ha^{-1})								
		Grain			Straw			Total		
		2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1	Farmers practices (N:P:K-75:45:30 kg ha^{-1} +1.5 t ha^{-1} farm yard manure)	615.37	616.62	616.00	421.95	416.33	419.14	1037.32	1032.95	1035.14
T_2	50% RDN (N:P: K - 50:30:20 kg ha^{-1})	567.71	555.28	561.50	367.88	365.29	366.59	935.60	920.57	928.09
T_3	Farm Yard Manure @ 5 t ha^{-1}	515.37	499.76	507.57	340.51	330.86	335.69	855.88	830.62	843.25
T_4	Vermicompost @ 2.5 t ha^{-1}	508.76	502.53	505.65	343.11	332.32	337.72	851.87	834.85	843.36
T_5	100% RDN (N:P: K - 100:60:40 kg ha^{-1})	681.12	692.84	686.98	453.16	455.71	454.44	1134.28	1148.55	1141.42
T_6	Fly ash @ 20 t ha^{-1}	439.72	432.67	436.20	309.09	313.75	311.42	748.80	746.42	747.61
T_7	Fly ash @ 30 t ha^{-1}	455.50	438.16	446.83	314.53	317.62	316.08	772.04	759.78	765.91
T_8	Fly ash @ 40 t ha^{-1}	457.78	440.90	449.34	316.94	321.84	319.39	772.72	758.75	765.74
T_9	Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	683.43	690.81	687.12	460.93	465.37	463.15	1144.36	1156.18	1150.27
T_{10}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	680.60	685.78	683.19	464.77	469.75	467.26	1145.36	1155.53	1150.45
T_{11}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	679.87	694.77	687.32	466.87	468.56	467.72	1146.74	1163.33	1155.04
T_{12}	Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	676.58	685.29	680.94	465.55	467.56	466.56	1142.13	1152.85	1147.49
T_{13}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	686.93	694.69	690.81	471.31	480.93	476.12	1158.24	1175.62	1166.93
T_{14}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	682.36	687.57	684.97	468.06	470.57	469.32	1150.43	1158.14	1154.29
T_{15}	50% RDN + Farm Yard Manure @ 5 t ha^{-1}	613.73	610.10	611.92	410.26	405.21	407.74	1023.99	1015.31	1019.65
T_{16}	50% RDN + Vermicompost @ 2.5 t ha^{-1}	618.09	611.00	614.55	417.51	409.94	413.73	1035.59	1020.94	1028.27
	SEm±	18.59	17.89	18.24	9.41	9.25	9.33	25.01	23.13	24.07
	CD (P=0.05)	53.28	51.68	52.48	27.17	26.72	26.94	73.09	66.82	69.96

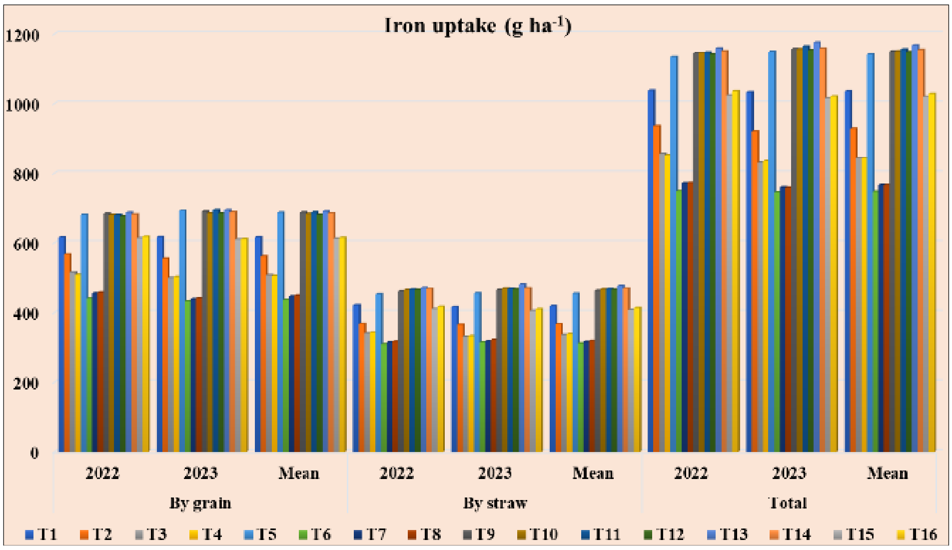

Fig 5: Effect of fly ash in combination of farm yard manure and vermicompost on iron uptake (g ha-1) of rice

3.3.3.2 Manganese (Mn) uptake by grain and straw (g ha^{-1})

Application of fly ash in combination with farm yard manure, vermicompost and inorganic fertilizer significantly increased the manganese uptake by grain and straw at harvest stage presented in table 6. and fig 6. Uptake of manganese in rice grain was significantly higher in the treatment T_{13} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) which noticed 369.93, 371.29 & 370.61 g ha^{-1}, during year 2022, 2023 & mean basis respectively when compared with other treatments, which found on par with T_5 (100 RDN), T_9 (Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{10} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{11} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{12} (Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) and T_{14} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}). The treatment T_6 (Fly ash @ 20 t ha^{-1}) recorded significantly lower manganese uptake in grain 247.14, 246.86 and 247.00 g ha^{-1}, during year 2022, 2023 and mean basis respectively.

Similarly higher manganese uptake by straw in treatment T_{13} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) which noticed 254.71, 255.35 & 254.87 g ha^{-1}, during year 2022, 2023 & mean basis respectively when compared with other treatments, which found on par with T_1 (Farmers practice), T_5 (100 RDN), T_9 (Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{10} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{11} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{12} (Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}), and T_{14} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}). The treatment T_6 (Fly ash @ 20 t ha^{-1}) recorded significantly lower manganese uptake in grain 208.97, 209.22 and 209.10 g ha^{-1}, during year 2022, 2023 and mean basis respectively (Table 6.). A significant difference was noticed in the total uptake of manganese by rice with an application of different levels of fly ash with a different combination depicted in table 6. and fig. 6. The treatment T_{13} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) recorded significantly higher total manganese uptake by the rice (628.64, 626.64 & 622.64 g ha^{-1} during 2022, 2023 & mean basis) when compared to other treatments and it was on par with treatment T_5 (100 RDN), T_9 (Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{10} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{11} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{12} (Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}), and T_{14} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}). Lower total manganese uptake was recorded in treatment T_6 (Fly ash @ 20 t ha^{-1}) with 456.10, 456.08 & 456.09 g ha^{-1} during 2022, 2023 & mean basis respectively.

Application of increased levels of fly ash combined with farm yard manure, vermicompost and inorganic fertilizes has significantly increased available iron and manganese content. Among different treatments, higher iron and manganese uptake were recorded with the application of Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}. This might be due to the fly ash application neutralized the soil acidity and thus increased the soil pH due to release of alkaline compounds from fly ash. The increase in soil pH also reduced phosphorus fixation with iron and manganese and thus reduced iron phosphate and manganese phosphate formation. Dissolution of iron oxide coatings with organic acids produced by microorganisms causing a release of iron phosphate and manganese phosphate and thus increased the availability of iron and manganese in the soil and leads higher uptake. Fly ash application along with farm yard manure contains essential plant nutrients that are released during the mineralization process and these factors increased the availability of nutrients and helps for better absorption and uptake by grain and straw of paddy. These results are corroborate with the findings of Sheela (2006) [8].

Another possible reason for increased iron and manganese uptake by rice grain and straw might be due to under paddy cultivation, ferric iron is reduced to ferrous iron and $Mn4^{+}$ to Mn^{2+} under anaerobic conditions thereby the solubility and mobility increases in soil for uptake by rice. The findings of Rautaray *et al.* (2003) [6] and Selvakumari *et al.* (2000) [7] also supports the results of increasing the

Table 6: Effect of fly ash in combination of farm yard manure and vermicompost on manganese uptake (g ha^{-1}) by rice

	Treatments	Manganese uptake (g ha^{-1})								
		Grain			Straw			Total		
		2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1	Farmers practices (N:P: K - 75:45:30 kg ha^{-1} + 1.5 t ha^{-1} Farm Yard Manure)	332.62	329.72	331.17	254.11	247.17	250.64	586.73	576.89	581.81
T_2	50% RDN (N:P: K - 50:30:20 kg ha^{-1})	308.43	302.09	305.26	233.46	234.33	233.90	541.88	536.42	539.15
T_3	Farm Yard Manure @ 5 t ha^{-1}	282.26	273.23	277.75	225.61	216.61	221.11	507.87	489.85	498.86
T_4	Vermicompost @ 2.5 t ha^{-1}	281.71	278.91	280.31	225.36	217.00	221.18	507.07	495.91	501.49
T_5	100% RDN (N:P: K - 100:60:40 kg ha^{-1})	366.61	363.33	364.97	256.63	251.17	253.90	623.25	614.51	618.88
T_6	Fly ash @ 20 t ha^{-1}	247.14	246.86	247.00	208.97	209.22	209.10	456.10	456.08	456.09
T_7	Fly ash @ 30 t ha^{-1}	255.87	246.93	251.40	213.68	214.09	213.89	469.54	461.03	465.29
T_8	Fly ash @ 40 t ha^{-1}	255.52	246.65	251.09	213.03	215.94	214.49	468.55	458.59	463.57
T_9	Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	366.37	361.47	363.92	252.45	253.66	253.06	618.83	615.14	616.99
T_{10}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	369.59	361.85	365.72	248.00	248.59	248.30	617.59	610.44	614.02
T_{11}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	365.36	362.69	364.03	252.15	252.96	252.56	617.51	615.66	616.59
T_{12}	Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	366.98	359.18	363.08	251.02	249.90	250.46	617.99	609.08	613.54
T_{13}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	369.93	371.29	370.61	254.71	255.35	254.87	628.64	626.64	622.64
T_{14}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	368.48	368.03	368.26	253.63	251.44	252.54	619.11	619.47	619.29
T_{15}	50% RDN + Farm Yard Manure @ 5 t ha^{-1}	323.56	315.80	319.68	234.68	228.24	231.46	558.25	544.05	551.15
T_{16}	50% RDN + Vermicompost @ 2.5 t ha^{-1}	328.75	320.16	324.46	243.08	235.04	239.06	571.84	555.19	563.52
	SEm±	9.27	10.78	10.02	6.02	4.85	5.44	13.94	12.67	13.31
	CD (P=0.05)	27.70	31.12	29.41	17.36	13.99	15.67	40.28	36.61	38.45

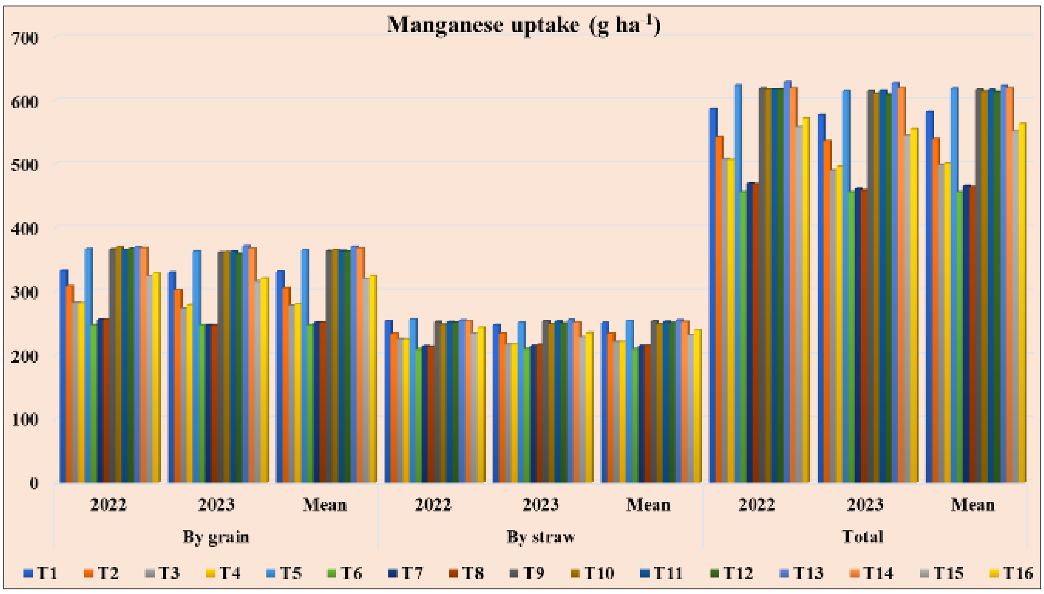

Fig 6: Effect of fly ash in combination of farm yard manure and vermicompost on manganese uptake (g ha^{-1}) of rice

3.3.3.3 Zinc (Zn) uptake by grain and straw (g ha^{-1})

The data presented in table 7. and fig. 7 indicate the effect of fly ash in combination with farm yard manure, vermicompost and inorganic fertilizers on uptake of zinc (Zn) by grain and straw at the harvest stage of the crop. Uptake of zinc by grain significantly increased with the application of higher levels of fly ash along with farm yard manure, vermicompost and inorganic fertilizers. However, the treatment T_{13} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) registered higher uptake of zinc by grain (120.95, 122.20 & 121.58 g ha^{-1} during experiment year 2022, 2023 & mean basis, respectively) which found superior over the treatment T_2 (50% RDN), T_3 (Farm Yard Manure @ 5 t ha^{-1}), T_4 (Vermicompost @ 2.5 t ha^{-1}), T_6 (Fly ash @ 20 t ha^{-1}), T_7 (Fly ash @ 30 t ha^{-1}) and T_8 (Fly ash @ 40 t ha^{-1}) during both the year of experimentation on mean basis. Significantly lower zinc uptake was observed in treatment T_6 (Fly ash @ 20 t ha^{-1}) with 85.47, 85.45 & 85.46 g ha^{-1} during year 2022, 2023 and mean basis.

In straw and total uptake of zinc by rice was increased significantly due to the combined application of fly ash with farm yard manure and vermicompost. Significantly higher uptake of zinc in straw and as well as total uptake was observed with the application of Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1} (T_{13}: 131.76, 134.87 & 133.32 g ha^{-1} during experiment year 2022, 2023 and mean basis and 252.71, 257.07 & 254.89 during experiment year 2022, 2023 and mean basis g ha^{-1}, respectively) over other treatments which found on par with treatment T_5 (100 RDN), T_9 (Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{10} (Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{11} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}), T_{12} (Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) and T_{14} (Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}) during both the year of experiment on mean basis. Significantly lower uptake of zinc in straw and total zinc uptake was observed in the T_6 (Fly ash @ 20 t ha^{-1}) (87.80, 88.03 & 87.92 and 173.26, 173.47 & 173.37 g ha^{-1}, respectively) during both the year of experimentation and on mean basis.

Table 7: Effect of fly ash in combination of farm yard manure and vermicompost on zinc uptake (g ha-1) by rice

	Treatments	Zinc uptake (g ha^{-1})								
		Grain			Straw			Total		
		2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1	Farmers practices (N:P: K-75:45:30 kg ha^{-1} + 1.5 t ha^{-1} farm yard manure)	115.02	114.18	114.60	119.39	119.19	119.29	234.42	233.36	233.89
T_2	50% RDN (N:P: K - 50:30:20 kg ha^{-1})	106.04	105.36	105.70	103.96	102.45	103.21	210.00	207.81	208.91
T_3	Farm Yard Manure @ 5 t ha^{-1}	97.98	95.49	96.74	96.78	93.37	95.08	194.77	188.85	191.81
T_4	Vermicompost @ 2.5 t ha^{-1}	98.19	97.09	97.64	96.79	94.18	95.49	194.98	191.28	193.13
T_5	100% RDN (N:P: K - 100:60:40 kg ha^{-1})	120.18	120.41	120.30	128.10	127.51	127.81	248.28	247.92	248.10
T_6	Fly ash @ 20 t ha^{-1}	85.47	85.45	85.46	87.80	88.03	87.92	173.26	173.47	173.37
T_7	Fly ash @ 30 t ha^{-1}	88.32	86.03	87.18	90.16	89.83	90.00	178.49	175.86	177.18
T_8	Fly ash @ 40 t ha^{-1}	89.15	87.10	88.13	92.56	91.86	92.21	175.71	174.96	175.34
T_9	Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	119.86	120.55	120.21	128.12	131.68	129.90	247.98	252.23	250.11
T_{10}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	120.04	119.61	119.83	129.52	132.10	130.81	249.56	251.71	250.64
T_{11}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	119.62	120.98	120.30	129.34	131.79	130.57	248.96	252.78	250.87
T_{12}	Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	119.73	120.25	119.99	129.34	132.04	130.69	249.08	252.29	250.69
T_{13}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	120.95	122.20	121.58	131.76	134.87	133.32	252.71	257.07	254.89
T_{14}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	120.37	121.06	120.72	130.80	132.66	131.73	251.18	253.72	252.45
T_{15}	50% RDN + Farm Yard Manure @ 5 t ha^{-1}	115.52	112.11	113.82	115.78	113.64	114.71	231.30	224.11	227.71
T_{16}	50% RDN + Vermicompost @ 2.5 t ha^{-1}	116.04	112.65	114.35	119.19	115.76	117.48	235.23	228.41	231.82
	SEm±	3.29	3.54	3.41	2.93	2.80	2.86	5.61	5.54	5.58
	CD (P=0.05)	9.51	10.22	30.26	8.47	8.10	8.28	9.52	16.01	12.77

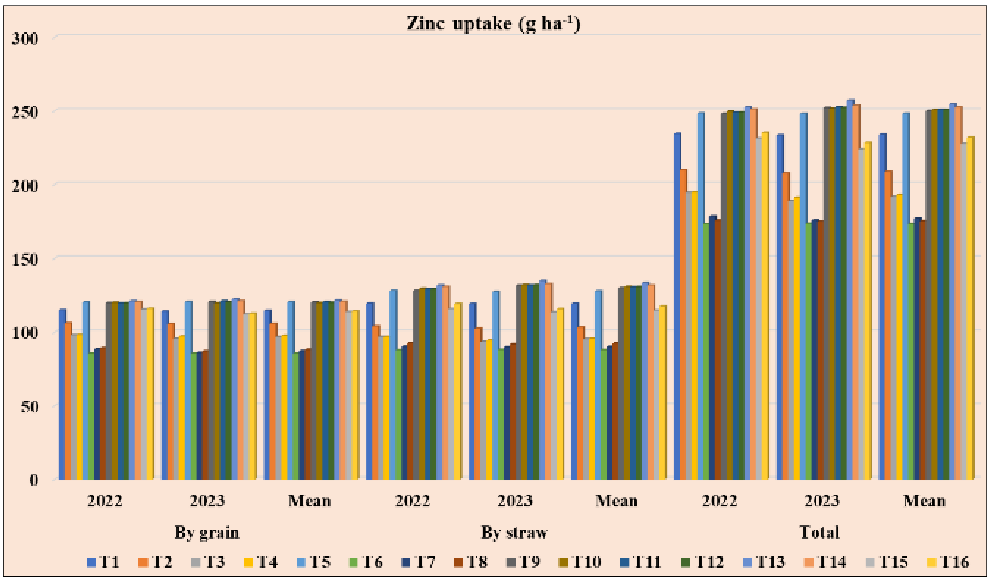

Fig 7: Effect of fly ash in combination of farm yard manure and vermicompost on zinc uptake (g ha^{-1}) of rice

3.3.3.4 Copper (cu) uptake by grain and straw (g ha^{-1})

The results presented in table 7. and fig. 8. which showed that the copper uptake by grain & straw and total copper uptake in rice was not found significant due to treatment of fly ash with farm yard manure & vermicompost and inorganic fertilizers. The higher uptake of zinc in grain, straw and as well as total uptake was observed with the application of Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1} (T_{13}: 19.84, 20.02 & 19.93 g ha^{-1}, 16.33, 16.67 & 16.50 g ha^{-1} and 36.18, 36.70 & 36.44 g ha^{-1}, respectively) during both the year of micronutrient study and on mean basis compared to all treatments. While, the lowest uptake of zinc in grain, straw and as well as total uptake was recorded in treatment T_6 Fly ash @ 20 t ha^{-1} (17.29, 16.93 & 17.11 g ha^{-1}, 13.95, 14,16 & 14.06 g ha^{-1} and 31.23, 31.49 & 31.36 g ha^{-1}, respectively) during both the year of micronutrient study and on mean basis.

The increase in micronutrient status of soil due to fly ash application might be attributed to two reasons; firstly, the direct addition of nutrients to the soil through fly ash and farm yard manure, secondly, due to favourable soil conditions associated with fly ash application and farm yard manure and vermicompost. This increased the availability of nutrients and helps in better absorption of micronutrients by grain and straw. Rani and Kalpana, (2010) [5] also reported the build-up of micronutrient cation in soil due to the application of fly ash. An increase in iron, manganese, copper and zinc status in soil due to application of fly ash @ 15 t ha^{-1} was also reported by Deshmukh *et al.* (2000) [2]. The findings of Rautaray *et al.* (2003) [6] and Selvakumari *et al.* (2000) [7] also support the results of increasing the micronutrient status of the experiment by fly ash application.

Micronutrients (iron, manganese, copper and zinc) content was increased by the increased levels of fly ash and with farm yard manure, RDN and vermicompost. This might be due to fly ash and farm yard manure are good sources of micronutrients that were mineralized by the microorganisms there by their availability and uptake by the crop was increased.

Table 8: Effect of fly ash in combination of farm yard manure and vermicompost on copper uptake (g ha^{-1}) by rice

	Treatments	Copper uptake (g ha^{-1})								
		Grain			Straw			Total		
		2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1	Farmers practices (N:P: K - 75:45:30 kg ha^{-1} + 1.5 t ha^{-1} Farm Yard Manure)	20.60	20.02	20.31	15.48	15.39	15.44	36.07	35.41	35.74
T_2	50% RDN (N:P: K - 50:30:20 kg ha^{-1})	19.36	18.90	19.13	13.80	13.95	13.88	33.16	32.85	33.01
T_3	Farm Yard Manure @ 5 t ha^{-1}	17.67	17.24	17.46	14.39	14.24	14.32	32.05	31.47	31.76
T_4	Vermicompost @ 2.5 t ha^{-1}	17.58	17.47	17.53	14.55	14.24	14.40	32.13	31.71	31.92
T_5	100% RDN (N:P: K - 100:60:40 kg ha^{-1})	19.51	19.76	19.64	16.06	16.12	16.09	35.58	35.88	35.73
T_6	Fly ash @ 20 t ha^{-1}	17.29	16.93	17.11	13.95	14.16	14.06	31.23	31.49	31.36
T_7	Fly ash @ 30 t ha^{-1}	17.87	17.10	17.49	14.17	14.32	14.25	32.04	31.82	31.93
T_8	Fly ash @ 40 t ha^{-1}	17.88	17.17	17.53	14.21	14.72	14.47	31.49	31.39	31.44
T_9	Fly ash @ 20 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	19.43	19.72	19.58	15.97	16.29	16.13	35.41	36.00	35.71
T_{10}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	19.50	19.60	19.55	16.08	16.34	16.21	35.58	35.94	35.76
T_{11}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Farm Yard Manure @ 5 t ha^{-1}	19.34	19.69	19.52	16.13	16.29	16.21	35.48	35.99	35.74
T_{12}	Fly ash @ 20 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	19.37	19.61	19.49	16.17	16.35	16.26	35.54	35.96	35.75
T_{13}	Fly ash @ 30 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	19.84	20.02	19.93	16.33	16.67	16.50	36.18	36.70	36.44
T_{14}	Fly ash @ 40 t ha^{-1}+ 100% RDN + Vermicompost @ 2.5 t ha^{-1}	19.58	19.80	19.69	16.24	16.53	16.39	35.81	36.33	36.07
T_{15}	50% RDN + Farm Yard Manure @ 5 t ha^{-1}	19.41	19.24	19.33	14.87	14.52	14.70	34.28	33.77	34.03
T_{16}	50% RDN + Vermicompost @ 2.5 t ha^{-1}	19.83	19.56	19.70	15.17	14.70	14.94	34.99	34.26	34.63
	SEm±	0.80	0.79	0.80	0.39	0.43	0.41	1.01	0.88	0.95
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

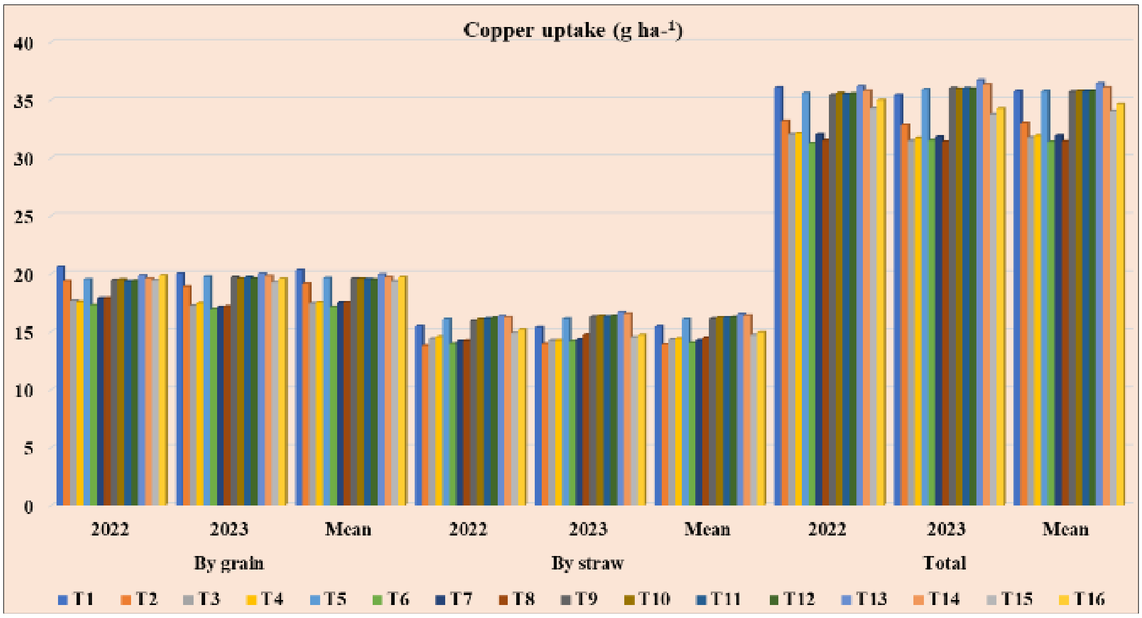

Fig 8: Effect of fly ash in combination of farm yard manure and vermicompost on copper uptake (g ha^{-1}) of rice

4. Conclusion

The study underscores the significance of early childhood education and the use of traditional games in fostering various developmental skills among children. The research findings indicate that traditional games play a crucial role in enhancing cognitive, social, and motor skills, contributing to holistic child development. Furthermore, the integration of traditional games in early childhood education curriculums has been shown to promote cultural heritage, social interaction, and physical activity among young learners.

The evidence gathered from various educational settings suggests that traditional games offer a valuable pedagogical tool that can complement modern educational techniques. These games not only provide an engaging and enjoyable learning experience but also help in the preservation of cultural traditions and the transmission of cultural knowledge to younger generations.

In conclusion, the inclusion of traditional games in early childhood education is highly beneficial and should be encouraged by educators, policymakers, and parents. By leveraging the educational potential of traditional games, we can support the development of well-rounded individuals who are connected to their cultural roots and equipped with essential life skills.

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