



Integrated Nutrient Management for Enhanced Maize Yield and Sustainability in Tamil Nadu, India

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ABSTRACT

Background: Studies across various regions reveal that declining crop yields and profits are not just caused by environmental damage and stress. Deficiencies in essential nutrients, both major and minor, also play a significant role. This is why integrating organic and inorganic source of nutrients is critical for ensuring food security and self-sufficiency for maize.

Methods: Field experiment was carried out to examine the integrated use of organic and inorganic sources of nutrients on maize growth and yield components at wetland farm, Tamil Nadu Agricultural University, Tamil Nadu during the 2018-19 to 2019-20 with 15 treatment combination under Split plot design with 3 replications. Main plot consist of five treatments of organic sources of nutrients i.e. M₁ (Fish pond silt from desi poultry dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha), M₂ (Fish pond silt from duck dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha), M₃ (Fish pond silt from turkey dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha), M₄ (FYM @ 12.5 t/ha), M₅ (No manure application) and three sub plot treatments consist of inorganic sources i.e. S₁ (100% recommended dose of NPK), S₂ (75% recommended dose of NPK) and S₃ (No fertilizer application).

Result: The results revealed that the highest grain yield (8293 kg ha⁻¹) and stover yield (11974 kg ha⁻¹) was obtained with the application of fish pond silt from duck dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha along with 100% recommended dose of NPK (M₂S₁) which was 116% and 132% higher to lowest grain yield (3845 kg ha⁻¹) and stover yield (5160 kg ha⁻¹) obtained in control (M₅S₃).

Key words: Fish pond silt, Inorganic fertilizer, Organic manure, Poultry droppings, Vermicompost.

INTRODUCTION

Maize, also known as corn (*Zea mays* L.), is a leading cereal crop, even surpassing rice and wheat in some areas. Maize is a crucial food source, contributing significantly to diets in India and around the world. Corn production in India has skyrocketed in recent decades, demonstrating its importance.

Having highest genetic yield potential among the cereals, maize is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions (Rajeshkumar *et al.*, 2018). Maize, which is globally known as the queen of cereals, has emerged as one of the significant foreign exchange earners under the commodities covered under the Agricultural and Processed Food Products Export Development Authority (APEDA) ambit. The export of maize has increased and touched USD 816.31 million during the financial year 2021-22 from USD 634.85 million achieved during 2020-21 and it has been continuously increasing due to higher production (GoI, 2022). In India, maize is grown in an area of 99.61 lakh hectares with production of 324.7 lakh tonnes and productivity of 3260 kg ha⁻¹ (Government of India, 2024) (Table 1).

Kalyanasundaram and Augustine (2021) reported that 15% yield increased when maize crop fertilized with 100% recommended dose of Inorganic nutrients in addition to 12.5 t ha⁻¹ along with slow release micronutrient granules as integrated nutrient management practice. Bindhani *et al.* (2007)

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reported that the application of 120 kg N ha⁻¹ resulted in tallest plant with maximum dry matter yield and leaf area index which is significantly higher than 80 kg N ha⁻¹. They also reported a significant increase in marketable baby corn plant⁻¹, fresh weight, length and girth with the

application of 120 kg N ha⁻¹. Sukhjinder and Misal (2022) reported that INM source has significantly increased the availability of nitrogen in soil and thus result in increasing the yield attributes like cob length, cob diameter, Number of grains cob⁻¹ were increased in maize. Kumar *et al.* (2017) revealed that treatment T₃ (150% RDF) recorded significantly higher growth parameters and yield attributes viz. plant height (201.90 cm), number of grains cob⁻¹ (393.20), test weight (223.25 g) and grain yield (52.05 q ha⁻¹) which was closely followed by treatment T₅ (RDF + 5 tons FYM ha⁻¹ and recorded higher plant height (200.30 cm), number of grains cob⁻¹ (391.95), test weight (223.15 g) and grain yield (51.70 q ha⁻¹) and was found to be at par to treatment T₃. Augustine and Imayavaramban (2022) revealed that the nutrient level treatments containing 50% RDF through NPK + 50% RDF through FYM with Fe and Zn as foliar application @ 0.5% led to highest growth and yield attributes, grain yield (8.52 t ha⁻¹) and stover yield (10.35 t ha⁻¹) and also resulted in maximum crude protein content (14.93%), starch content (63.85 mg g⁻¹), Fe (36.25 mg kg⁻¹) and Zn (29.35 mg kg⁻¹) in maize grain. Mehta *et al.* (2005) reported significant increase in cobs plant⁻¹ with application of 100% RDF along with FYM at 10 t ha⁻¹ over control. Shabnam *et al.* (2011) state that application of FYM @ 5 t ha⁻¹ and lime @ 0.3 t ha⁻¹ recorded maximum dry matter accumulation, leaf area index and crop growth rate and produced higher grain (4.162 t ha⁻¹) and stover (9.823 t ha⁻¹) yields of maize under red and lateritic soils of Ranchi. Sujatha *et al.* (2008) reported that application of sunhemp green manure + poultry manure + 100% RDN gave significantly higher total dry matter accumulation plant⁻¹ leaf area index and cob yield plant⁻¹ in maize over rest of treatment combinations. Yadhav and Christopher Lourduraj

(2006) reported that the application of organic manures, FYM, poultry manure, green leaf manure and panchagavya spray resulted in significant increase in yield attributes of sweet corn such as cob length, cob diameter and number of grains per cob.

Research indicates that several factors can limit corn yields, including nutrient deficiencies, harsh weather conditions and pests and diseases. To address these challenges and ensure food security, farmers are increasingly adopting integrated nutrient management (INM) practices.

MATERIALS AND METHODS

Field experiments were conducted at wetland farm, Tamil Nadu Agricultural University, Tamil Nadu during 2018-19 and 2019-20. The experimental field is geographically situated in North Western agro-climatic zone of Tamil Nadu at 11°N latitude and 77°E longitudes with an altitude of 426.7 meters above mean sea level (MSL). The soil of the experimental field is clayey loam in texture with good drainage. The soil nutrient status of the field during start of the experiment was low in available nitrogen, high in available phosphorus and high in available potassium. The detailed physico-chemical characteristics of the soil are given in (Table 2) and nutrient status of fish pond silt from different ponds are given in (Table 3). Rice-blackgram-maize cropping system was adopted in *rabi*, summer and *kharif* seasons, respectively. TNAU maize hybrid (COH (M) 6) with the duration of 110 days was selected for the study. Recommended spacing between rows is 60 cm and between plants 25 cm under ridges and furrow system of land configuration. Details of the crops in experiment are given in (Table 4). The INM treatments include the

Table 1: Maize production over the years from 2014-15 to 2023-24 (Gol, 2024).

Year	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24
Total (Lakh tonnes)	241.7	225.7	259	287.5	277.2	287.7	316.5	337.3	380.8	324.7

Table 2: Physico-chemical properties of the experimental soil.

Particulars	Values	
	I year	II year
Textural composition		
Clay (%)	45.7	45.9
Silt (%)	15.4	15.4
Coarse sand (%)	19.9	19.8
Fine sand (%)	22.6	22.7
Textural class	Clay loam	Clay loam
Chemical constituent		
Soil reaction (pH)	8.4	8.3
Electrical conductivity (dS m ⁻¹)	0.43	0.44
Organic Carbon (%)	0.64	0.72
Available N (kg/ha)	259.4	264.1
Available P (kg/ha)	22.3	23.8
Available K (kg/ha)	487.8	491.6

application of organic waste from the allied components of integrated farming system, either composted or recycled Treatments system. The experiment was laid out in split plot design with three replications with a plot size of 6 m × 4 m (Table 5).

Silt was collected from fish pond and applied to the first crop (rice) @ 5 t/ha. Vermicompost obtained from allied components was applied @ 5 t/ha for both rice and maize crops, respectively for the treatments M_1 to M_3 . Whereas FYM alone @ 12.5 t/ha was applied to M_4 for rice and maize crops. The application of organic manure as recycled desi poultry droppings, turkey droppings and duck droppings was applied as fish pond silt @ 5 t/ha to rice crop before the planting as per the treatment schedule. Farmyard manure was applied @ 12.5 t/ha to first two crops in the system except blackgram and vermicompost was applied @ 5 t/ha to the first two crops in the system in both the years of study. In maize, vermicompost was applied at vegetative and flowering stages. With regard to fish pond silt application, silt from the trial run poultry, duck and turkey droppings fed ponds were collected and used as recycled manure for the first year trial and from the experimental pond for the succeeding year at the rate of 5 t/ha (Table 6). Inorganic fertilizer in the form urea, single super phosphate and muriate of potash were applied to meet the crop demand. With respect to nitrogen three split doses were applied, 25% at basal (135.6 kg/ha), 50% (271.2 kg/ha) at 25 days after sowing and remaining 25% (135.6 kg/ha) was applied at 45 days after sowing. 100% phosphorus (468.7 kg/ha) and potassium (125.3 kg/ha) were applied at basal just before sowing.

Growth parameters were recorded at 30, 60 and 90 DAS during both the years. Plant height was measured from the base of the plants to the tip of the longest leaf stretched and expressed in cm. Yield observation was recorded by adopting standard procedure from the five tagged plants. Cob length (cm), number of grain rows/cob and Grains (Numbers/cob) and grain and stover yield were recorded after drying to the recommended moisture level from the net plot and expressed in kg/ha. The available N, P and K were expressed in kg/ha and the organic carbon content was expressed in per cent.

Nutrient uptake (kg/ha) =

$$\frac{\text{Percentage of nutrients} \times \text{Total dry matter production (kg/ha)}}{100}$$

Following the statistical analysis methods outlined by Gomez and Gomez (2010), were examined the data collected on various characters involved in the study. Whenever the analysis revealed statistically significant differences between the treatments, critical differences (CD) was calculated at 0.05 probability level to compare the groups. For treatments where no significant differences were found, the notation "NS" was used to indicate.

RESULTS AND DISCUSSION

Effect of INM practices on plant height

The plant height was significantly influenced by the application of organic manures and different levels of inorganic fertilizers during both the years of experimentation. The higher plant height was recorded with fish pond silt from duck dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha combined with 100% recommended dose of NPK (M_2S_1) which was followed by fish pond silt from desi poultry dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha along with 100% recommended dose of NPK (M_1S_1). In organic manure applied plots, higher plant height was recorded with fish pond silt from duck dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha (M_1) and it was followed by fish pond silt from desi poultry dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha (M_2) and it was found to be on par with M_4 and M_3 . The lowest plant height was recorded with no manure application (M_5). Similar results were obtained at both 60 DAS and 90 DAS. Application of 100% recommended dose of NPK (S_1) to maize produced taller plants and it was followed by the application of 75% recommended dose of NPK (S_2) and the lowest values were recorded with no fertilizer application (S_3) at all stages during both the years of experimentation (Table 7). In agreement with the present findings, Adekiya *et al.* (2020) also reported that comparable plant height was achieved in maize plants with the application of integrated nutrients from organic and inorganic sources, inorganic fertilizer and organic manure alone. This could be because the integrated application of organic manure and NPK improves the overall soil condition that can increase nutrient uptake compared to mineral fertilizers alone thereby boosting the vegetative growth of the plants. The taller plants with high number of leaves observed in this study under M_2S_1 treatment has implications on the yield components as these plants may be able to intercept more solar radiation and therefore produce more photosynthates for partitioning to the ear and grains.

Effect of INM practices on dry matter production

Organic manure application boosted maize dry matter production (DMP) in a rice-blackgram-maize cropping system, compared to no manure or inorganic fertilizer use. This effect was observed at 30, 60 and 90 days after sowing (DAS) in both years of the experiment. The best DMP results came from combining fish pond silt (duck-fed pond) and vermicompost (5 tons/hectare each). This treatment (M_2) was slightly better than using fish pond silt from a desi poultry-fed pond with vermicompost (M_1). Treatments M_4 and M_3 showed similar DMP, while plots with no manure application (M_5) consistently had the lowest DMP across all stages and years. Inorganic fertilizer application also significantly affected maize DMP. The recommended NPK dose (S_1) led to the highest DMP, followed by 75% of the recommended dose (S_2). Plots with no fertilizer application

(S₃) had the lowest DMP at all observation points in both years (Table 8). Overall, both organic manure source and fertilizer level significantly impacted maize DMP in the rice-blackgram-maize system. As regards to interaction the treatment combining fish pond silt (duck-fed pond) and vermicompost with the recommended NPK dose (M₂S₁) produced the highest DMP, followed by M₁S₁. Whereas, the lowest DMP was produced with no manure or fertilizer application (M₅S₃). Higher dry weight of maize was recorded in the integrated use of organic manure combined with NPK

and farmyard manure indicated that the organic matter served as an energy source for the soil microorganisms, which converts inorganic nutrients in the soil or applied in the form of fertilizers to readily available form for utilization by the plants. Geng *et al.* (2019) also found that organic manure integrated with NPK was influenced the maize plants significantly to accumulate higher drymatter might be due to higher solubility and speedy release of nutrients besides providing favorable rhizosphere for maize to utilize higher amount of nutrients. The increased dry matter in the

Table 3: Nutrient status of fish pond silt from different ponds.

Chemical constituents	Composition		
	Silt from Fish - Desi poultry pond	Silt from Fish - Duck pond	Silt from fish - Turkey fed pond
Soil reaction (pH)	8.4	8.1	8.3
Electrical conductivity (dS m ⁻¹)	0.59	0.49	0.57
Organic carbon (%)	0.81	0.86	0.76
Available N (kg/ha)	289	296	277
Available P (kg/ha)	21.8	22.9	21.2
Available K (kg/ha)	494.1	497.5	489.3

Table 4: Details of the crop in the experiment.

Crop	Variety	Duration (Days)	Season	Spacing (cm)	2018-19		2019-20	
					Date of sowing/ Date of transplanting*	Date of harvest	Date of sowing/ Date of transplanting*	Date of harvest
Rice	CO (R) 50	130-135	Rabi	20 × 10	02.11.18 27.11.18*	16.03.19	01.11.19 25.11.19*	16.03.20
Blackgram	TNAU CO 6 Blackgram	60-65	Summer	30 × 10	25.03.19	30.05.19	10.04.20	14.06.20
Maize	TNAU maize hybrid CO H(M) 6	110	Kharif	60 × 25	23.06.19	10.10.19	03.07.20	20.10.20

Table 5: Treatment details of the experiment.

Main plot	Treatment details
M ₁	Fish pond silt from desi poultry dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha
M ₂	Fish pond silt from duck dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha
M ₃	Fish pond silt from turkey dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha
M ₄	Farmyard manure 12.5 t/ha
M ₅	No manure application
Sub plot	
S ₁	100% recommended dose of NPK
S ₂	75% recommended dose of NPK
S ₃	No fertilizer application

Table 6: Recommended organic manure and fertilizer schedules for various crops in the cropping system is given below.

Crop	Organic manure application (t/ha)			Fertilizer schedule (kg/ha)		
	Farmyard manure	Pond silt	Vermicompost	Nitrogen	Phosphorus	Potassium
Rice	12.5	5.0	5.0	150	50	50
Blackgram	-	-	-	25	50	25
Maize	12.5	-	5.0	250	75	75

integrated poultry manure and NPK treatments could be ascribed to the continuous steady release of nutrients which might have enabled the leaf area duration to extend, thereby enabling photosynthesis to continue to occur for a longer period allowing more dry matter accumulation in the plant (Ponmozhi *et al.*, 2019).

Effect of INM practices on yield parameters and yield

Cob length, Number of grains per cob and test weight

The cob length, number of grains per cob and test weight was significantly influenced by the application of organic

manures and inorganic fertilization to maize in rice - blackgram - maize cropping system which increased cob length, number of grains per cob and test weight over no manure application. The higher cob length, number of grains per cob and test weight were recorded with the application of fish pond silt from duck dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha (M_2) which were on par with M_1 , M_3 and M_4 the lower cob length, number of grains per cob and test weight was recorded with no manure application (M_5) during both the years of experiment (Table 9). Applying different organic manures and fertilizer

Table 7: Effect of INM treatments on plant height of maize in rice-blackgram-maize cropping system (2 years pooled data).

Treatments	30 DAS (cm)				60 DAS (cm)				90 DAS (cm)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	111.3	102.7	90.1	101.4	191.3	170.6	154.8	172.2	214.4	189.8	169.3	191.2
M_2	114.5	105.6	92.5	104.2	198.8	182.4	161.9	181.0	219.2	196.3	175.2	196.9
M_3	107.4	97.5	83.4	96.1	175.9	156.3	138.9	157.0	202.0	181.5	160.4	181.3
M_4	109.2	100.9	88.2	99.4	184.7	164.9	145.4	165.0	208.5	185.4	165.4	186.4
M_5	94.7	81.2	70.2	82.0	163.2	144.3	121.0	142.8	179.1	151.6	142.4	154.1
Mean	107.4	97.6	84.9		182.8	163.7	144.4		204.7	180.9	160.4	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	5.1	4.0	9.0	9.1	9.1	6.9	15.7	15.6	5.9	3.6	8.9	8.1
CD (P=0.05)	11.8	8.5	20.1	NS	21.1	14.5	33.5	NS	13.8	7.5	19.3	NS

Table 8: Effect of INM treatments on dry matter production of maize in Rice-blackgram-maize cropping system (2 years pooled data).

Treatments	30 DAS (kg/ha)				60 DAS (kg/ha)				90 DAS (kg/ha)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	4516	3891	3037	3815	10213	8691	6782	10213	21257	18083	14112	17817
M_2	4728	3987	3119	3945	10929	8904	6956	10929	21769	18528	14474	18257
M_3	4133	3522	2743	3466	9368	7867	6302	9368	19200	16472	13078	16250
M_4	4319	3739	2915	3658	9820	8352	6511	9820	20412	17378	13547	17112
M_5	3389	2853	2108	2783	7570	6089	4840	7570	15694	12643	10071	12803
Mean	4217	3599	2784		10213	8691	6782	10213	19666	16621	13056	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	104	171	329	382	212	107	288	238	896	822	1748	1839
CD (P=0.05)	241	356	NS	NS	489	222	634	497	2066	1715	3614	NS

Table 9: Effect of INM treatments on yield attributes of maize in Rice-blackgram-maize cropping system (2 year pooled data).

Treatments	Cob length (cm)				No. of grains/cob				Test weight (g)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	23.3	19.8	18.3	20.5	573	522	469	521	39.43	39.32	39.11	39.29
M_2	23.8	20.9	18.6	21.1	587	531	478	532	39.91	39.47	39.17	39.52
M_3	21.7	18.9	16.6	19.1	542	489	413	481	39.02	38.74	38.64	38.8
M_4	22.4	19.3	17.7	19.8	558	510	458	509	39.37	39.11	38.73	39.07
M_5	19.3	17.1	15.7	17.4	482	447	396	442	38.94	38.68	38.12	38.58
Mean	22.1	19.2	17.4		548	500	443		39.33	39.06	38.75	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.9	1.0	2.0	2.3	18	16	34	35	0.97	1.02	2.10	2.28
CD (P=0.05)	2.0	2.1	4.7	NS	42	32	78	NS	NS	NS	NS	NS

combinations significantly impacted maize yield and its key characteristics, like cob length, number of grains per cob and grain weight. This effect was observed over two years of study. The best results, including increased cob length, grain number per cob and grain weight, were achieved using a combination of duck droppings as pond silt at 5 tons per hectare with vermicompost at 5 tons/ha along with 100% recommended NPK (M_2S_1). This was closely followed by a combination of recycled desi poultry droppings as fish pond silt at 5 tons/ha with vermicompost at 5 tons/ha along with 75% recommended NPK (M_1S_1). In both years, adding the recommended amount of NPK fertilizer to the duck droppings as pond silt and vermicompost 5 t/ha resulted in similar improvements in cob length, grain number per cob and overall yield, compared to the recycled desi poultry droppings treatment with the same additions. These findings align with previous research by Ravi *et al.* (2012) showed that pond silt manure improves soil properties like water holding capacity and aeration, which benefit root growth, nutrient uptake and ultimately maize growth and yield. The experimental findings revealed that use of organic and inorganic fertilizers in proper combination can gave higher yields than the sole application of either of the fertilizer or manure particularly in hybrid corn as reported by Abbasi *et al.* (2010). Application of higher levels of organic manure significantly improved various maize growth and yield parameters. This is consistent with the observations of Priyavart Mishra *et al.* (2019).

Grain yield

In a two-year study on maize in the rice-blackgram-maize cropping system, adding organic manure significantly boosted maize grain yield. The best results came from applying a combination of fish pond silt from a duck-fed pond (5 tons per hectare) and vermicompost (5 tons per hectare). This treatment (M_2) significantly yielded 6965 kg/ha when compared to fish pond silt from a turkey-fed pond with vermicompost (M_3) 6252 kg/ha. However, M_1 produced significantly more grain yield 6797 kg/ha than plots with the turkey-fed pond silt and vermicompost (M_3) and the control group with no manure (M_0), which had produced the lowest yield in both years. Similarly, maize grain yield increased with higher fertilizer application rates. Plots receiving 100% of the recommended NPK fertilizer dose (S_1) produced the highest grain yield (7508 kg/ha), followed by those with 75% NPK (S_2). Unsurprisingly, plots with no fertilizer application (S_3) had the lowest yield in both years (Table 10). Interestingly, the type of organic manure and fertilizer level interacted significantly to affect maize grain yield. The highest grain yield 8293 kg/ha came from the combination of duck-fed pond silt and vermicompost (each at 5 tons per hectare) with 100% recommended NPK (M_2S_1). This was followed by plots receiving desi poultry-fed pond silt with vermicompost and 100% NPK (M_1S_1). Plots with no manure or fertilizer application produced the least grain

yield. In simpler terms, using a combination of duck-fed pond silt and vermicompost along with recommended fertilizer levels led to the best maize grain yields in rice-blackgram-maize cropping system. The higher grain yield of maize in this study for the combined application of organic manure as poultry dropping fed pond silt combined with vermicompost along with NPK gave superior plants in terms of vegetative growth, which translated to better yield traits and the higher yield. The rapid development of the source also gave more time for the reproductive phase allowed more time for photosynthesis and partitioning of dry matter to the ears and grain. This could have contributed to the general higher yield obtained in the INM treatments. Essilfie *et al.* (2024) accounted particularly for the higher yield in the integrated treatment. The superiority of the integrated application of organic manure with NPK was also visible in the vegetative parameters such as plant height, number of leaves and shoot dry weight of the maize plants given them the comparative advantage to assimilate more photosynthates for partitioning to the ears and grains. This high vegetative growth translated to yield components such ear length and diameter and ultimately the higher yield of the integrated organic manure with NPK application compared to NPK alone.

Stover yield

The higher stover yield 9679 kg/ha were recorded with the application of fish pond silt from duck dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha (M_2) which were on par with M_1 (9210 kg/ha) but, it was significantly differs from the application of fish pond silt from turkey dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha (M_3) (8309 kg/ha) and the lower stover yield 6535 kg/ha was recorded with no manure application (M_0) during both years. Application of 100% RDF (S_1) recorded higher yield of 10323 kg/ha and it was significantly differ from the application of 75% RDF (S_2) (8506 kg/ha) and the lower stover yield was recorded with no fertilizer application (S_3) during both the years (Table 10). Application of different sources of organic and levels of fertilizer NPK produce significant interaction effect on stover yield of maize. The combined application of fish pond silt from duck-fed ponds (5 tons per hectare) and vermicompost (5 tons per hectare) with 100% recommended NPK resulted in the greatest stover yield 11974 kg/ha. This was on par with plots receiving fish pond silt from desi poultry fed ponds with vermicompost @ 5 t/ha + 100% NPK (11137 kg/ha). Plots with no manure and no fertilizer application had the least stover yield

Effect of INM practices on nitrogen, phosphorus and potassium uptake

Application of different sources of organic manure and levels of fertilizer NPK significantly influenced nitrogen, phosphorus and potassium uptake of maize. The maximum uptake was recorded with the application of fish pond silt from duck dropping fed pond @ 5 t/ha and vermicompost

@ 5 t/ha (M_2) (24.04, 111.10 and 162.65 kg/ha of N, 19.26, 27.88 and 39.60 kg/ha of P, 50.28, 147.71 and 216.42 kg/ha of K at 30, 60 and 90 DAS respectively) was found to be on par with (M_1) and significantly differ with other treatments. The lower nitrogen uptake was recorded with no manure application (M_5) at all stages of observation during both the years. The graded level of fertilizer application has marked influence on nitrogen, phosphorus and potassium uptake in maize. The higher nitrogen, phosphorus and potassium uptake was recorded with the application of recommended

dose of NPK 100% (S_1) (26.47, 119.44 and 174.46 kg/ha of N, 20.20, 29.62 and 42.39 kg/ha of P, 53.70, 158.27 and 231.76 kg/ha of K at 30, 60 and 90 DAS respectively) was followed by the application of 75% recommended dose of NPK (S_2) and the lower value was recorded with no fertilizer application (S_3) during both the years (Table 11, 12 and 13). Interaction between organic and inorganic fertilizer level was significant at all stages. The combined application of fish pond silt from duck dropping fed pond @ 5 t/ha and vermicompost @ 5 t/ha + 100 per cent recommended NPK

Table 10: Effect of INM treatments on grain and stover yield of maize in rice-blackgram-maize cropping system (2 years pooled data).

Treatments	Grain yield (kg/ha)				Stover yield (kg/ha)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	8097	6905	5388	6797	11137	9284	7208	9210
M_2	8293	7074	5526	6965	11974	9574	7489	9679
M_3	7334	6378	5045	6252	9812	8362	6755	8309
M_4	7802	6694	5173	6556	10648	8911	6920	8826
M_5	6014	4861	3845	4907	8046	6398	5160	6535
Mean	7508	6382	4996		10323	8506	6707	
	M	S	M at S	S at M	M	S	M at S	S at M
SEd	197	212	434	474	570	339	841	757
CD (P=0.05)	453	442	NS	NS	1313	706	NS	NS

Table 11: Effect of treatments on nitrogen uptake of maize in rice-blackgram-maize cropping system (Pooled data of 2 years).

Treatments	30 DAS (kg/ha)				60 DAS (kg/ha)				90 DAS (kg/ha)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	27.99	23.21	18.42	23.21	129.42	109.01	85.79	108.07	188.42	157.43	124.58	156.81
M_2	28.92	24.17	19.04	24.04	132.76	111.73	88.82	111.10	194.87	163.56	129.52	162.65
M_3	25.87	20.49	16.91	21.09	117.31	99.56	79.47	98.78	169.56	144.51	118.47	144.18
M_4	27.13	22.78	17.29	22.40	122.74	104.76	81.02	102.84	180.39	153.40	120.95	151.58
M_5	22.44	16.17	14.68	17.76	94.95	76.36	60.71	77.34	139.04	114.27	86.78	113.36
Mean	26.47	21.36	17.27		119.44	100.29	79.16		174.46	146.63	116.06	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.37	0.36	0.77	0.82	6.59	5.45	11.94	12.19	10.23	6.87	16.19	15.37
CD (P=0.05)	0.86	0.76	1.64	1.71	15.21	11.37	NS	NS	23.59	14.33	NS	NS

Table 12: Effect of treatments on phosphorus uptake of maize in rice-blackgram-maize cropping system (2 year pooled data).

Treatments	30 DAS (kg/ha)				60 DAS (kg/ha)				90 DAS (kg/ha)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	21.79	18.58	15.67	18.68	32.19	26.49	20.67	26.45	44.88	38.9	29.36	37.71
M_2	22.68	19.18	15.91	19.26	34.78	27.65	21.20	27.88	48.79	39.86	30.14	39.60
M_3	19.70	17.14	14.64	17.16	28.14	23.98	18.67	23.60	41.32	35.22	27.43	34.65
M_4	20.27	17.98	14.90	17.72	29.93	25.46	19.84	25.08	43.96	37.39	27.99	36.45
M_5	16.55	14.17	12.30	14.34	23.07	17.78	13.78	18.21	32.99	26.11	21.67	26.92
Mean	20.20	17.41	14.68		29.62	24.27	18.83		42.39	35.49	27.32	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	1.10	0.74	1.74	1.65	0.59	0.49	1.07	1.09	1.10	1.88	3.61	4.21
CD (P=0.05)	2.54	1.54	NS	NS	1.35	1.02	2.30	2.28	2.55	3.93	NS	NS

Table 13: Effect of treatments on potassium uptake of maize in rice-blackgram-maize cropping system (2 year pooled data).

Treatments	30 DAS (kg/ha)				60 DAS (kg/ha)				90 DAS (kg/ha)			
	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean	S ₁	S ₂	S ₃	Mean
M ₁	58.45	49.22	38.41	48.69	171.23	144.51	113.63	143.12	249.63	210.87	165.38	208.63
M ₂	60.63	50.43	39.78	50.28	176.28	148.06	118.79	147.71	259.98	218.55	170.73	216.42
M ₃	52.28	44.56	35.67	44.17	154.67	130.82	104.89	130.13	226.58	193.10	155.43	191.70
M ₄	54.28	47.30	36.87	46.15	163.30	138.87	109.98	137.38	241.04	204.99	159.81	201.95
M ₅	42.87	32.47	27.41	34.25	125.87	101.11	80.48	102.49	181.55	148.77	118.80	149.71
Mean	53.70	44.79	35.63		158.27	132.67	105.55		231.76	195.26	154.03	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	2.46	2.31	4.89	5.17	7.03	6.94	14.49	15.51	11.56	8.26	19.00	18.46
CD (P=0.05)	5.68	4.82	10.47	10.78	16.20	14.47	NS	NS	26.66	17.21	NS	NS

(M₂S₁) registered higher nutrient uptake (28.92, 132.76 and 194.87 kg/ha of N, 22.68, 34.78 and 48.79 kg/ha of P, 60.63, 176.28 and 259.98 kg/ha of K at 30, 60 and 90 DAS respectively), it was followed by (M₁S₁) and the lowest nutrient uptake was recorded with no manure and no fertilizer application (M₅S₃). The amount of nutrients a crop absorbs depends on both the concentration of nutrients in the soil and how much the crop is growing. This means that nutrient uptake increases as the crop matures. A healthy root system with lots of branches is crucial for taking in nutrients from the soil and moving them throughout the plant (Kumar *et al.*, 2007). Higher nutrient uptake was recorded in application of duck dropping as pond silt @ 5.0 t/ha combined with vermicompost @ 5.0 t/ha along with 100 per cent recommended dose of NPK fertilizers during both years (Table 11, 12 and 13). This might be due to higher crop productivity of this system and also diversified crops raised in the cropping system which led to higher nutrient uptake.

Crops absorbed more nutrients in 2019-20, likely due to improved soil health from past crop left-overs and organic manure. This better nutrient availability at the start of the growing season fuelled stronger plant growth, allowing them to take up even more nutrients throughout their lifecycle. The key contributor to this enhanced nutrient uptake might be the combined application of 5 tons per hectare each of duck manure and vermicompost. These organic amendments likely boosted soil organic carbon and other nutrients, while also increasing the availability of phosphorus by dissolving previously locked-up forms and preventing them from becoming unavailable again. Study investigated the impact of adding recycled poultry manure (desi poultry, duck and turkey) as pond silt at the rate of 5 t/ha, vermicompost at 5 t/ha and farm yard manure at 12.5 t/ha with 100 per cent recommended nitrogen, phosphorus and potassium. Compared to plots with no manure or fertilizer, the combined application of these composted materials and NPK fertilizer significantly increased the uptake of NPK by plants in both years of the study. This suggests that composted poultry manure and vermicompost may have a longer-lasting effect due to their slower decomposition,

gradually releasing nutrients and leading to higher overall NPK uptake in the cropping system. The results were comparable to those using just FYM. Combined application of organic and inorganic fertilizers strengthened soil structure and nutrient availability, ensuring an adequate nutrient supply during critical growth stages. Furthermore, the application of organic manures, in combination with inorganic ones, not only supplements nutrients through efficient absorption and utilization of nitrogen, phosphorus and potassium nutrients but also enriches the soil with organic matter, fostering long-term soil health. These findings align with previous research by Chandrawanshia *et al.* (2023) and Wang *et al.* (2024).

CONCLUSION

India's growing population has led to increased demand for maize, a vital crop for nutritional needs. Maize, being a nutrient-intensive crop, requires a balanced diet of macro and micronutrients to thrive. Organic fertilizers offer numerous benefits, including ecological balance, cost-effectiveness, environmental friendliness and production of nutritious food without compromising human health. Combining organic and inorganic fertilizers can enhance their effectiveness, reduce the reliance on costly chemical fertilizers and boost both yield and quality stability of maize crops. From the field study it can be concluded that, adding different organic materials and NPK fertilizers at various levels to maize grown in a rice-blackgram-maize rotation significantly influenced yield components, grain production and stover output. The combination of recycled duck droppings as pond silt at 5 tons per hectare with vermicompost (5 tons/ha) along with the full recommended dose of NPK nutrients (250:75:75 NPK kg/ha) led to the greatest nutrient uptake and NPK addition within the cropping cycle. To achieve higher maize crop yield, promote better farm waste recycling and sustainability in production organic manure at the rate of 5 tons/ha each (duck droppings + vermicompost) combined with full NPK nutrient application is recommended.

Conflict of interest

All authors declare that they have no conflicts of interest.

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