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Integration of organic supplements and inorganic nutrients levels on productivity and profitability of maize (*Zea mays*) in acidic soil of Assam

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Maize (*Zea mays* L.) is a globally important cross-pollinated crop, that belongs to the Poaceae family. India produced 33.6 million tonnes from 10 million hectares with a productivity of 3,349 kg/ha during 2022–23 (GOI 2023). In Assam, the area, production and yield of maize remain low compared to other states of India. Currently, about 41,154 ha of land are covered by maize, which produced 1,47,902 tonnes, with an average yield of 3.59 tonnes/ha (Directorate of Economics and Statistics, Govt. of Assam 2021). In present-day agriculture, the excessive use of chemical fertilizers to boost crop yields has become widespread (Ali *et al*. 2020). Chemical fertilizers alone are not adequate for sustaining soil fertility in the long term. Replacing chemical fertilizers with organic options has been shown to elevate soil *p*H, enhance nutrient levels and boost microbial biomass (Iqbal *et al*. 2020). Application of farmyard manure (FYM) @16 t/ha enhances soil water retention and improves nutrient availability. Additionally, the use of organic manures extended the duration of nutrient availability in maize-based cropping systems (Abid *et al*. 2020). Applying 100% of the recommended NPK along with 10 t FYM/ha led to the highest growth parameters and yields, compared to treatments using only organic or chemical farming methods (Jamakhandi *et al*. 2024). Keeping the above points in view a study was undertaken to know the effect of integrated use of organic and inorganic sources of nutrients on productivity, profitability and soil fertility in maize crop. The study also aimed to standardize nutrient doses to boost the productivity of improved maize varieties to meet the growing feed demand for promoting livestock farming in the region.

A study was carried out during the rainy (*kharif*) season of 2023–24 to evaluate the impacts of integrating locally available and popular organic supplements like FYM, vermicompost and inorganic nutrients levels on the performance of maize (*Zea mays* L.) in the acidic soil of Assam. The soil in the experimental field was sandy loam, consisting of 70.5% sand, 11% silt, and 18.4% clay; acidic with a *p*H of 4.84, electrical conductivity of 0.12 dS/m, bulk density of 1.31 g/cm^3, high in organic carbon content (1.18%), low in available nitrogen (197.6 kg/ha) and phosphorus (9.26 kg/ha) and available potassium was moderate (121.8 kg/ha). The experiment was arranged using a split-plot design (SPD), with three organic supplements, viz. Control (no organic supplements), Farmyard manure (FYM) @10 t/ha and Vermicompost (VC) @2.5 t/ha] in main plot and four inorganic nutrients levels (Control, 50% RDF (NPK), 75% RDF (NPK) and 100% RDF (NPK) along with 300 kg lime/ha with all levels) in sub plot and replicated thrice. The FYM consisted of NPK (0.5%, 0.2% and 0.5%) and was applied 15 days before sowing. The vermicompost consisted of NPK (1.5%, 0.8% and 1.5%) was applied just before sowing. FYM and vermicompost were selected as organic supplements due to their ability to improve soil organic matter, enhance microbial activity, and supply essential nutrients. Their buffering capacity helps to mitigate soil acidity, promoting better nutrient availability and plant growth in acidic soils. The maize hybrid 'LQMH-1' was selected due to its high quality, which may get a premium price in the market and it has the potential to boost the income of farmers. Moreover, this hybrid is specifically recommended for the north-east region. The crop was sown on 3 August 2023, using 20 kg seeds/ha @60 cm apart rows with 20 cm plant spacing. The recommended dose of fertilizer 60:40:40 kg/ha of N, P_2O_5 and K_2O was applied through urea, DAP and MOP, respectively. The crop was harvested on 5 November 2023. Following the harvest, threshing was carried out and the seed yield was measured in t/ha. For growth and yield parameters, five plants/plot were randomly chosen and data were collected. All other standard practices of maize cultivation were followed during

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experimentation.

Partial factor productivity (PFP) was determined using the formula proposed by Dobermann (2007). The gathered data were statistically analyzed using analysis of variance (ANOVA) through the OPSTAT software. The standard error of the mean (SEM±) and the least significant difference (LSD) @5% significance level were computed for each treatment and treatment means were compared based on these values. PFP was calculated as:

$$PFP = Y_f/N_a$$

Where Y_f, Yield obtained (kg/ha); N_a, Nutrient applied (kg/ha).

The economic analysis was determined as follows, net returns were determined by deducting the cultivation cost from the total returns. The B:C ratio was determined by dividing the net returns by the total cultivation cost.

Interaction impact of treatments on yields: Integration of organic supplements and inorganic nutrients was found better than applying either of these separately. The combined application of organic manures and nutrient levels significantly enhanced grain, stover, and overall biological yields of the crop (Table 1). The highest grain (4.84 t/ha), stover (8.65 t/ha), and biological (13.49 t/ha) yields were obtained with the application of 10 t FYM/ha along with 100% RDF (NPK) compared to the other treatment combinations. It produced 105%, 71.28% and 82% more grain yield, stover and biological yield, respectively, over control along with control. It was statistically similar with 10 t/ha of FYM along with 75% RDF (NPK) and 2.5 t/ha of vermicompost along with 100% RDF (NPK) and superior over all other combinations. This could be due to improved soil moisture content, increased nutrient availability, better nutrient uptake, sustained nutrient supply and enhanced protection from erosion compared to the control treatment (Ali *et al.* 2020). The integration of 10 t FYM/ha along with 100% RDF enhances crop yield through complementary mechanisms. Physiologically, FYM improves root growth and nutrient uptake by increasing organic acids and microbial activity, while RDF ensures immediate nutrient availability. Chemically, FYM enhances soil organic matter, cation exchange capacity and nutrient retention, creating a synergistic effect that maximizes yield potential. Organic sources of nutrients provide almost all the essential nutrients in a balanced amount to the crop. Besides, the slow release of nutrients from these sources due to the slow mineralization process may be able to supply the nutrients as and when it is required by the crop. Combining organic manures with chemical fertilizers has proven effective in not only maintaining higher yields but also enhancing stability in crop production (Jjagwe *et al*. 2020). For sustained crop nourishment, vermicompost is recommended as a beneficial organic manure for integrated field crop management practices (Shakunthala *et al*. 2018). The integrated nutrient management (INM) practices, which involve the integrated use of organic and inorganic nutrients, greatly improved maize performance (Paramesh *et al*. 2023). The use of lime to decrease soil acidity and mitigate the harmful concentrations of manganese (Mn) and aluminium (Al) is essential for attaining optimal crop yields in acidic soils (Mokidul *et al*. 2021). The positive impact of INM results from the stabilization of applied nutrients through organic sources, which are then gradually released to meet the demand of the growing crop (Bezboruah and Dutta 2021).

Partial factor productivity (PFP): The PFP values varied significantly depending on the organic supplements and inorganic nutrients levels used (Fig. 1). The application of FYM @10 t/ha recorded significantly higher PFP of nitrogen (78.5) and phosphorus (142.2) as compared to vermicompost @2.5 t/ha and control. However, it was similar with vermicompost @2.5 t/ha, and the control recorded a significantly higher PFP of K (96.3). The lowest PFP of N (64.23) and P (96.35) was recorded with the treatment control and the lowest PFP of K (89.64) was recorded with treatment FYM. Among the inorganic nutrients levels, control recorded significantly higher PFP for N (87.5)

Table 1 Interaction impact of organic supplements and inorganic nutrients levels on grain yield, stover yield and biological yield of maize

Treatment	Control	FYM (10 t/ha)	Vermicompost (2.5 t/ha)	Mean
Grain yield (t/ha)				
Control	2.36	3.91	3.71	3.33
50% RDF (NPK)	3.36	4.14	4.01	3.83
75% RDF (NPK)	3.65	4.58	4.42	4.21
100% RDF (NPK)	3.83	4.84	4.61	4.43
Mean	3.30	4.37	4.19	3.95
SEM ±			0.11	
LSD (*P*=0.05)			0.31	
Stover yield (t/ha)				
Control	5.05	7.42	7.23	6.57
50% RDF (NPK)	6.62	8.23	7.74	7.53
75% RDF (NPK)	7.02	8.42	8.16	7.86
100% RDF (NPK)	7.41	8.65	8.46	8.17
Mean	6.53	8.18	7.90	7.53
SEM ±			0.17	
LSD (*P*=0.05)			0.50	
Biological yield (t/ha)				
Control	7.41	11.33	10.95	9.90
50% RDF (NPK)	9.98	12.37	11.74	11.36
75% RDF (NPK)	10.67	13.00	12.57	12.08
100% RDF (NPK)	11.25	13.49	13.07	12.60
Mean	9.83	12.54	12.08	11.48
SEM ±			0.21	
LSD (*P*=0.05)			0.63	

RDF, Recommended dose of fertilizer.

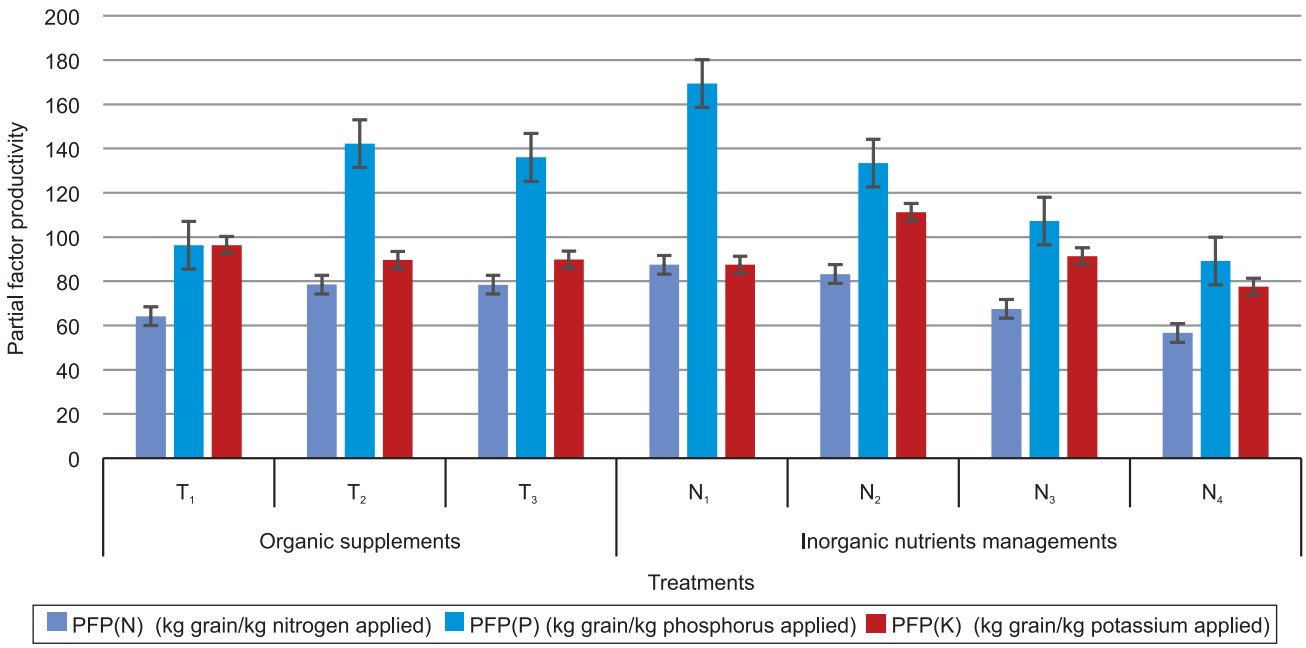

Fig. 1 Effect of organic supplements and inorganic nutrients management levels on partial factor productivity (PFP) of N, P and K. Refer to methodology for Treatment details.

and P (169.4) in comparison to the other treatments, and 50% RDF (NPK) measured significantly higher PFP for K (111.3) in comparison to the other treatments. 100% RDF (NPK) measured the lowest PFP of N (56.68), P (89.24), and K (77.58). This was due to the application of the highest amount of NPK through 100% RDF (NPK). These finding aligns with the observations reported by Rawal *et al*. (2021). These results can guide the application of chemical fertilizers in cropping systems based on maize, thereby promoting the efficiency of nutrient utilization (Lodh *et al*. 2024).

Interaction impact of treatments on economics: Maximizing profits is crucial for farmers to sustain their livelihoods and support food and nutrition security. Analyzing the economic outcomes of the harvest provides valuable insights into the financial benefits of various treatments. There was a significant interaction between organic supplements and inorganic nutrients levels on economics (Table 2). The highest gross returns were obtained by FYM @10 t/ha with 100% RDF (NPK) i.e. 129.3 $\times 10^3$ ₹/ha. This was notably greater than the other treatment combinations. It was statistically similar to vermicompost @2.5 t/ha with 100% RDF (NPK) and FYM @10 t/ha with 75% RDF (NPK). The highest net returns were obtained by FYM @10 t/ha with 100% RDF (NPK) i.e. 80.04$\times 10^3$ ₹/ha which was notably greater than the other treatment combinations. It was statistically similar with vermicompost @2.5 t/ha with 100% RDF (NPK) and FYM @10 t/ha with 75% RDF (NPK). The reason is self-explanatory that 100% RDF responded maximum with respect to QPM grain as well as stover yields resulting in maximum net returns. Comparable results were also observed by Jinjala *et al.* (2016). The highest net B:C ratio was obtained by control with 100% RDF i.e. 1.85 which was significantly higher than the other treatment combinations. It was statistically at

Table 2 Interaction impact of organic supplements and inorganic nutrients levels on the economics of maize

Treatment	Control	FYM (10 t/ha)	Vermicompost (2.5 t/ha)	Mean
Gross returns ($\times 10^3$ ₹/ha)				
Control	65.07	105.58	100.72	90.46
50% RDF (NPK)	91.26	112.62	108.46	104.12
75% RDF (NPK)	98.76	122.88	118.69	113.44
100% RDF (NPK)	103.84	129.31	123.78	118.98
Mean	89.73	117.60	112.91	106.75
SEM±		2.44		
LSD (*P*=0.05)		7.26		
Net returns ($\times 10^3$ ₹/ha)				
Control	35.68	63.29	60.73	53.23
50% RDF (NPK)	57.48	65.94	64.08	62.50
75% RDF (NPK)	63.68	74.91	73.01	70.53
100% RDF (NPK)	67.46	80.04	76.81	74.77
Mean	56.08	71.04	68.66	65.26
SEM±		2.44		
LSD (*P*=0.05)		7.26		
Net B:C ratio				
Control	1.21	1.50	1.52	1.41
50% RDF (NPK)	1.70	1.41	1.44	1.52
75% RDF (NPK)	1.82	1.56	1.60	1.66
100% RDF (NPK)	1.85	1.62	1.64	1.70
Mean	1.65	1.52	1.55	1.57
SEM±		0.05		
LSD (*P*=0.05)		0.16		

RDF, Recommended dose of fertilizer.

par with the control with 75% RDF (NPK) and the control with 50% RDF (NPK). These findings closely align with the observations of Shakunthala *et al*. (2018). The cost of cultivation was increased due to the additional incorporation of FYM and vermicompost at various application rates. Although an increase in yield was observed, the benefit-cost ratio showed a lower proportion due to minimal returns and elevated production costs (Gudade *et al*. 2022).

SUMMARY

The field experiment was conducted during the rainy (*kharif*) season of 2023–24 to assess the impact of the integrated application of organic supplements and inorganic nutrients on maize in acidic soil. The highest grain, stover and biological yields and gross and net returns were obtained from the use of 10 t FYM/ha with 100% RDF (NPK). It was statistically similar to vermicompost @2.5 t/ha with 100% RDF (NPK) and FYM @10 t/ha with 75% RDF (NPK). This combination is also more cost-effective compared to other treatment combinations. Among organic supplements, the significantly highest PFP for N and P was obtained from the application of 10 t FYM/ha. Among inorganic nutrients levels, control recorded significantly higher PFP for N and P. Regular soil testing and the balanced use of organic and inorganic nutrients should be emphasized to optimize nutrient availability and enhance maize productivity, especially for acidic soil regions.

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