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An Economic Evaluation of Maize–Mustard Cropping System in Response to the Complementary Influence of Organic and Inorganic Source of Nutrients

P. M. Rao[1*], G. E. C. H. Vidya Sagar[2], K. Suresh[3], G. Padmaja[4] and S. Narender Reddy[5]

[1]Dept. of Agronomy, Agricultural Research station, Karimnagar, PJTAU, Telangana (505 001), India
[2]Dept. of Agronomy, [4]Dept. of Soil science, [5]Dept. of Crop Physiology, PJTAU, Hyderabad, Telangana (500 030), India
[3]Dept. of Agronomy, Water Technology Centre, PJTAU, Hyderabad, Telangana (500 030), India

Corresponding Author

P. M. Rao
e-mail: polasanimadhukar@gmail.com

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Abstract

A field experiment was conducted during *kharif,* 2018 and 2019 and *rabi*, 2018–19 and 2019–20 at the Regional Agricultural Research Station, Polasa, Jagtial, to evaluate the effect of integrated nutrient management (INM) practices on yield attributes, yield, and economics of maize in a maize–mustard cropping system. The experiment on maize during *kharif* was laid out in a randomized block design with nine treatments and three replications. The treatments included N_1: 100% recommended dose of fertilizers (RDF);N_2:75% recommended dose of nitrogen (RDN)+25% N through farmyard manure (FYM); N_3:75% RDN+25% N through vermicompost; N_4: 75% RDN+25% N through poultry manure; N_5: 75% RDN+25% N through sheep manure; N_6: 75% RDN+25% N through neem cake; N_7: 75% RDN+*Azotobacter* at 5 kg ha^{-1}; N_8: 75% RDN+*Azospirillum* at 5 kg ha^{-1}; and N_9: 75% RDN+*Azotobacter* at 2.5 kg ha^{-1}+*Azospirillum* at 2.5 kg ha^{-1}. Each main plot was further subdivided into four subplots during the *rabi* season to accommodate mustard treatments under a split-plot arrangement. The fertilizer treatments imposed on mustard included F_1: 0:0:0 kg ha^{-1} N:P:K (control); F_2: 30:20:20 kg ha^{-1} NPK (50% RDF); F_3: 45:30:30 kg ha^{-1} NPK (75% RDF); and F_4: 60:40:40 kg ha^{-1} NPK (100% RDF). Recommended agronomic practices were followed for both crops throughout the experiment. The study evaluated the effect of organic, inorganic, and biofertilizer sources on productivity and profitability of the maize–mustard system. Economic parameters including gross returns, net returns, and benefit–cost ratio were calculated to assess feasibility of nutrient management practices. The findings highlighted sustainable nutrient management strategies for improving maize-based cropping systems.

Keywords: Maize, mustard, INM, productivity, profitability, biofertilizers, sustainability, economics

1. Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops globally, ranking third after wheat and rice in terms of area and production. Its high genetic yield potential, adaptability to diverse agro-climatic conditions, and multiple uses as food, feed, and industrial raw material make it indispensable for ensuring global food and nutritional security. Globally, maize contributes nearly 8% of the total cereal area and about 25% of total cereal production, reflecting its superior productivity compared to other cereals (Anonymous, 2023; Shiferaw et al., 2019). In India, maize is cultivated across varied agro-ecological regions and plays a significant role in agricultural growth and livelihood security. As per CMIE (2019–20), maize occupies 95.69 lakh ha with a production of 287.65 lakh t and an average productivity of 3006 kg ha^{-1}. In Telangana, it covers 5.61 lakh ha with a production of 29.99 lakh t and a productivity of 5347 kg ha^{-1}, indicating considerable scope for further yield enhancement through improved agronomic practices (Anonymous, 2021). Nutrient management is a key determinant of maize productivity and yield attributes. Being a nutrient-exhaustive crop with rapid growth and high biomass accumulation, maize requires substantial quantities of nitrogen (N), phosphorus (P), and potassium (K) throughout its growth cycle (Bindraban et al., 2020). Exclusive dependence on chemical fertilizers, though effective in meeting immediate crop nutrient requirements, often leads to soil degradation, nutrient imbalances, and declining factor productivity over time. In contrast, organic nutrient sources such as farmyard manure, vermicompost, green manure, and crop residues contribute to improved soil structure, water-holding capacity, and enhanced microbial activity (Agegnehu et al., 2017). Organic inputs play a crucial role in nutrient cycling and transformation. They promote microbial-mediated processes that convert unavailable nutrient forms into plant-available forms, ensuring a steady nutrient supply (Lal, 2020). However, sole reliance on organic sources may not suffice to meet the nutrient demand of high-yielding maize hybrids under intensive cropping systems (Vanlauwe et al., 2019). Therefore, integrating organic and inorganic nutrient sources is essential for achieving optimal productivity and maintaining soil health. Integrated Nutrient Management (INM), which combines chemical fertilizers, organic manures, and biofertilizers, is widely recognized as a sustainable approach to nutrient management. INM enhances nutrient use efficiency, improves soil organic carbon status, and promotes beneficial soil microbial populations (Jat et al., 2018). It also minimizes nutrient losses and environmental pollution while sustaining long-term soil fertility. Cropping systems play a vital role in INM, as nutrient dynamics are influenced by crop sequence, residue recycling, and nutrient removal patterns. Thus, balanced fertilization based on system-level nutrient budgeting is essential for sustaining overall system productivity. Maize-based cropping systems, particularly maize–mustard sequences, are widely practiced and require efficient nutrient management strategies. These systems are often intensive, leading to rapid depletion of soil nutrients if not managed properly. Integration of chemical fertilizers with organic manures and biofertilizers has shown synergistic effects, resulting in improved crop growth, higher yields, enhanced nutrient uptake, and better soil fertility status (Aryal et al., 2021; Patra et al., 2023). INM practices have been reported to significantly improve productivity and sustainability of maize-based systems (Kemal and Abera, 2015a). Considering the importance of maize–mustard cropping systems and the need for sustainable nutrient management, the present study was undertaken to evaluate the effect of integrated nutrient management practices on yield attributes, yield, and economics of maize. The objective was to identify efficient nutrient management strategies that enhance productivity, profitability, and long-term soil health under maize–mustard cropping systems.

2. Materials and Methods

The experiment was conducted during two consecutive *kharif* and *rabi* seasons of 2018–19 and 2019–20, respectively at Regional Agricultural Research Station, Polasa, Jagtial, Northern Telangana Zone of Telangana state. The soil of experimental site was sandy loam with pH of 7.7, Electrical conductivity 0.23 dS m^{-1}, low in organic carbon (0.30%), low in available nitrogen (180 kg ha^{-1}) and medium in phosphorus (53 kg ha^{-1}) and high in potassium (315 kg ha^{-1}). The experiment was laid out in a randomized block design for maize during *kharif*, 2018 and 2019, situated at latitude of 25°36′ North and longitude of 83°09′ East, with altitude of 86.0 m above the mean sea level. The experiment was laid out in a randomized block design for maize during *kharif*, 2018 and 2019 with nine treatments consisting of 100% RDF, 75% RDN+25% N through FYM, 75% RDN+25% N through vermicompost, 75% RDN+25% N through poultry manure, 75% RDN+25% N through sheep manure, 75% RDN+25% N through neem cake, 75% RDN+*Azotobacter* at 5 kg ha^{-1},75 % RDN+*Azospirillum* at 5 kg ha^{-1}, 75% RDN+*Azotobacter* at 2.5 kg ha^{-1}+*Azospirillum* at 2.5 kg ha^{-1}. Crop was sown at spacing of 60×20 cm^2 on 27th June during 2018 and 26th June during 2019. Organic manures were applied (on equal N basis) as per the treatment and incorporated into the soil two weeks before sowing. Crop was fertilized with uniform level of 60 kg P_2O_5 and 50 kg K_2O ha^{-1}. Half of the total N and full P and K fertilizers were applied at the time of sowing. Remaining N was applied at knee high stage by pocketing method and free living *Azotobacter sp*, *Azospirillum sp* were incorporated in soil at the time of sowing. The required amount of N, P and K fertilizers was applied through urea, SSP and Muriate of potash, respectively. Other cultural operations and plant protection measures were followed as per the recommendations. Crop received 603 mm (31 rainy days) and 746 mm (44 rainy days) rainfall during the crop growth period in 2018 and 2019, respectively. DHM-117 Hybrid of maize and Black gold variety of mustard were used for sowing of experiment. Application of organic and inorganic nutrient sources were done as per treatment. Other crop management practices were followed as per the recommendation of the area. Observation were recorded as per standard procedure. The recorded data were subjected to statistical analysis as prescribed by Gomez and Gomez. The interpretation of the treatment effects were made on the basis of Fisher's critical difference at p=0.05 level.

3. Results and Discussion

3.1. Economic evaluation of fertilizer vs organic source of nitrogen

Farmers adjudge the technologies to be adopted not only in terms of production but the economic challenges. On this premise the economic evaluation of different treatments owing to the substitution of 25% nitrogenous fertilizer to the recommended level of 200 kg ha^{-1} N to maize was presented.

The data in table 1 narrated the existing price of different organic manures within 50 km radius of the experimental site at the Regional Agricultural Research Station, Polasa, Jagtiyal. The urea fertilizer which had the highest concentration of 46% N cost ₹ 5.70 kg^{-1}. The cost of 50 kg N through urea was ₹ 620. Literature abounds that the fertilizers were expensive. Hence, there was a need to integrate different sources of organic matter to replace part of the recommended level of nitrogen to crops (Tetarwal et al., 2011; Nagavani et al., 2015; Abbas et al., 2020; Vinay et al., 2020). This was untrue. The organic manures studied in the present investigation negate this myth. The most popular farmyard manure was estimated to possess 0.49% N in 2018 and the sample assessed in 2019 had 0.52% N on dry weight basis. The moisture content of this manure was not consistent in different samples. Mohiteet et al. (2024)

Table 1: Cost of different sources of nitrogen

Source of nitrogen	Nitrogen (%)	Quantity (kg)	Cost (₹ kg^{-1})	Total cost (₹)
2018				
Urea	46.0		5.7	621
Farmyard manure	0.49	14000	1.25	17500
Vermicompost	2.1	3000	6.0	18000
Poultry manure	1.8	4000	1.7	6800
Sheep manure	2.8	2000	1.4	2800
Neem cake	4.8	1000	8.0	8000
2019				
Urea	46.0		5.7	621
Farmyard manure	0.52	13000	1.25	16250
Vermicompost	2.20	3000	6.0	18000
Poultry manure	1.60	4000	1.7	6800
Sheep manure	2.92	2000	1.4	2800
Neem cake	5.0	1000	8.0	8000

Urea ₹ 266 / (bag of 45 kg)$^{-1}$; Farmyard manure ₹ 18,750 / (Lorry load of 15 t^{-1}; Vermicompost ₹ 6 kg^{-1}; Poultry manure ₹ 20,400 /(Lorry load of 12 t)$^{-1}$ and Sheep manure ₹3,500 / (tractor trolley load of 2.5 t)$^{-1}$; The quantity of organic manures applied to substitute 25% nitrogen i.e., 50 kg N ha^{-1} and the amount were rounded; The nitrogen per cent was based on dry matter basis; The quantity of farmyard manure, vermicompost and poultry manure was adjusted to 40% moisture content at the time of application

reported that vermicompost with high moisture content ≥40% was sticky. It posessed difficulty in uniform spread. Dry manure with <30% blow in the direction of wind and did not settled uniform on the soil. It should be air dried to a moisture content of around 40% at the time of application. The quantity of manure to be applied should be appropriated to the optimum moisture content to adjust the nitrogen content to be applied based on the pre estimated nitrogen percentage in the sample. Following this advice, the quantity of farmyard manure applied was 12.75 t ha^{-1} in the first year and 12.01 t ha^{-1} in the second year. Vermicompost applied was 14.28 t ha^{-1} in the first year and 13.63 t ha^{-1} in the second year. Poultry manure applied was 5.38 t ha^{-1} in the first year and 5.31 t ha^{-1} in the second year. The expenses on this quantity of farm yard manure increased almost 20 times to ₹12,755 ha^{-1}. Vermicompost required 23 times more amount of ₹ 14,286 expenditure than fertilizer urea poultry manure required 8.7 times more amount of ₹ 5,380 expenditure than fertilizer urea. Sheep manure was 4 times more expensive than urea; it costed ₹2,500 to supply the same quantity of 50 kg N ha^{-1} as others. This was due to relatively more N concentration and low cost of ₹ 1.40 kg^{-1}. Neem cake was about 13.4 times more expensive than urea for equivalent N content. It costed ₹ 8,333 ha^{-1} during 2018. The expenses on this quantity of farmyard manure increased almost 20 times to ₹ 12,019 ha^{-1}. Vermicompost required 22 times more amount of ₹ 13,636 expenditure than fertilizer urea poultry manure required 8.6 times more amount of ₹ 5,313 expenditure than fertilizer urea. Sheep manure was 3.9 times more expensive than urea; it costed ₹ 2,397 to supply the same quantity of 50 kg N ha^{-1} as others. This was due to relatively more N concentration and low cost of ₹ 1.40 kg^{-1}. Neem cake was about 12.9 times more expensive than urea for equivalent N content. It costed ₹ 8,000 ha^{-1} during 2018.

The breath breaking consciousness of farmers especially the rainfed peasants defy the adoption of such expensive technologies even if they returned high profits. The practical approaches were appreciated by the frequently drought stuck farmers. Maintenance of 1 or 2 dairy animals and/or few sheep and goats was an integral part of the farming practice in India. Small and marginal farmers earn 15–20% of the income as insurance from these sources. A cow or buffalo eat the crop residue of rice or any millet like jowar or maize etc., at 2% body weight (Mohammad and Singh, 2018). An acre of crop residue along with the farm wastes, weeds and wastes of vegetables and fruits were sufficient to feed 2 large animals year^{-1}. An adult cow or buffalo produce around 10 t farm yard manure and 2–4 l milk day^{-1}. A herd of 10 sheep or goats were less costly and easy to maintain than the large ruminants. They produced 10 t pellets a year. They also produced more kids and were sold easy. They were the cushions of shock in years of crop failures due to low and uncertain rains (Mohammad, 2020). Therefore, Farmyard manure or goat manure was almost all available with farmers without any expenses. Vermicompost was also prepared by the farmers. However, poultry manure needs to be purchased. Only few big farmers have poultry farms. Neem cake was also to be purchased from other sources.

3.2. Economic evaluation of maize

The economics of maize in response to different integrated nutrient management treatments in relation to the recommended level of inorganic fertilizers was furnished in Table 2.

3.2.1. Gross return (₹ ha^{-1})

Higher gross return recorded with application of 75% RDN+25% N through vermicompost (₹ 1,24,444 and ₹ 1,31,560 during 2018 and 2019, respectively) which was comparable with 100% RDF (₹ 1,22,790 and ₹ 1,28,292 during 2018 and 2019 respectively), 75% RDN+25% N through farmyard manure (₹ 1,18,255 and ₹ 1,25,849 during 2018 and 2019 respectively), 75% RDN+25% N through sheep manure (₹ 1,06,848 during 2018) over 75% RDN+25% N through poultry manure, 75% RDN+25% N through neem cake, 75% RDN+*Azotobacter* at 2.5 kg ha^{-1}+*Azospirillum* at 2.5 kg ha^{-1}, 75% RDN+*Azospirillum* at 5 kg ha^{-1}. Lower gross return was recorded with application of 75% RDN+*Azotobacter* at 5 kg ha^{-1} (₹ 90,058 and ₹ 95,421 during 2018 and 2019 respectively).

Table 2: Economics of maize as influenced by integrated nutrient management treatments

Treatments	Gross returns (₹ ha^{-1})			Net returns (₹ ha^{-1})			B:C ratio		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
T_1- 100% RDF	122790	128292	125541	89540	95042	92291	3.69	3.86	3.78
T_2-75% RDN+25% N through FYM	118255	125849	122052	69505	78349	73927	2.43	2.65	2.54
T_3-75% RDN+25% N through vermicompost	124444	131560	128002	75194	82310	78752	2.53	2.67	2.60
T_4-75% RDN+25% N through poultry manure	105839	112891	109365	67789	74841	71315	2.78	2.97	2.88
T_5-75% RDN+25% N through sheep manure	106848	114821	110835	73198	81171	77185	3.18	3.41	3.30
T_6-75% RDN+25% N through neem cake	101839	108620	105230	62589	69370	65980	2.59	2.77	2.68
T_7-75% RDN+Azotobacter at 5 kg ha^{-1}	90058	95421	92740	58308	63671	60990	2.84	3.01	2.93
T_8-75% RDN+Azospirillum at 5 kg ha^{-1}	95606	101500	98553	63856	69750	66803	3.01	3.20	3.11
T_9-75% RDN+Azotobacter at 2.5 kg ha^{-1}+Azospirillum at 2.5 kg ha^{-1}	98469	103462	100966	66719	71712	69216	3.10	3.26	3.18
SEm±	8438	8549		7667	7568		0.25	0.26	
CD (*p*=0.05)	17889	18123		16254	16044		0.53	0.55	

The price of maize grain was ₹ 17 kg^{-1} and ₹ 17.6 kg^{-1} during 2018 and 2019, respectively; Price of maize stalk ₹ 2 kg^{-1} during 2018 and 2019.

3.2.2. Net returns (₹ ha^{-1})

Higher net returns recorded with application of 100% RDF (₹89,540 and ₹ 95,042 during 2018 and 2019 respectively) which was comparable with 75% RDN+25% N through vermicompost (₹ 75,194 and ₹ 82,310 during 2018 and 2019 respectively), 75% RDN+25% N through farmyard manure (₹ 1,18,255 and ₹ 1,25,849 during 2018 and 2019 respectively), 75% RDN+25% N through sheep manure (₹ 81,171 during 2019) over 75% RDN+25% N through poultry manure, 75% RDN+25% N through neem cake, 75% RDN+*Azotobacter* at 2.5 kg ha^{-1}+*Azospirillum* at 2.5 kg ha^{-1}, 75% RDN+*Azospirillum* at 5 kg ha^{-1}. Lower net return was recorded with application of 75% RDN+*Azotobacter* at 5 kg ha^{-1}(₹ 58,308 and ₹ 63,671 during 2018 and 2019 respectively).

3.2.3. B:C ratio

Higher B:C ratio was recorded with application of 100% RDF (3.69 and 3.86 during 2018 and 2019 respectively) which was comparable with 75% RDN+25% N through sheep manure (3.18 and 3.41 during 2018 and 2019 respectively) over 75% RDN+25% N through farmyard manure, 75% RDN+25% N through vermicompost, 75% RDN+25% N through poultry manure, 75% RDN+25% N through neem cake, 75% RDN+*Azotobacter* at 2.5 kg ha^{-1}+*Azospirillum* at 2.5 kg ha^{-1}, 75% RDN+*Azospirillum* at 5 kg ha^{-1}, 75% RDN+*Azotobacter* at 5 kg ha^{-1}. Lower B:C ratio was recorded with application of 75% RDN+ 25% N through farmyard manure (2.43 and 2.65 during 2018 and 2019 respectively).

The cost of cultivation of maize with the existing practice of fertilizer application was ₹ 33,250 ha^{-1}. If 25% nitrogenous fertilizer was substituted with Farm yard manure, the expenses increased considerably. If purchased an additional cost of ₹ 17,500 were incurred in the first year raising the total to ₹ 48,750 ha^{-1}. In the second year, farmyard manure worth ₹ 16,250 ha^{-1} increased the cultivation expenses to ₹ 47,500 ha^{-1}. The gross returns after the sale of produce were ₹ 1,18,255 in the first year and ₹ 1,25,849 ha^{-1} in the second year. The net returns were ₹ 69,505 and ₹ 78,349 in the corresponding years. The profit was less than due to fertilizer application which recurred ₹ 89,540 and ₹ 95,042. The benefit cost ratio reduced to 2.43 from 3.69 due to fertilizer application in 2018. This economic variable reduced from 3.86 to 2.65 in 2019. In practice small and marginal farmers depending on rainfed farming could not afford to purchase such expensive organic manure. Most of the farmers herd a small unit of ruminants and not only got the farmyard manure or sheep manure in their own premises but also earned subsidiary returns from the byproducts like milk and sale of the progeny. Even vermicompost was also a practical viability for the farmers to prepare in their own fields. They did not afford to spend huge money on their purchase. Poultry manure increased the cost of cultivation, but reduced the profit ha^{-1} and rupee^{-1}

returns. Most farmers did not venture on this manure. Only few farmers if they owned poultry farm certainly applied this manure and save ₹ 620 ha^{-1} on 110 kg urea. It was inapt to spend huge amount on neem cake.

Mean profit of rupees 3.69 rupee^{-1} was incurred in 2018 and 3.86 in 2019. There was a steep reduction in the profit in terms of rupees rupee^{-1} invested in the order of sheep manure, poultry manure, neem cake, vermicompost and farmyard manure. Mean reduction over two years was 87, 75, 70, 68 and 66% due to the substitution of these organic manures over the nitrogenous fertilizer. A practical consideration was that most of the farmers rear cattle and did not really purchase this manure. Therefore, still this might be considered a valid proposition than to invest more on the purchase of other sources of organics.

The substitution of 25% N through farmyard manure, vermicompost or sheep manure had several advantages in improving the soil physical, chemical and biological properties. Continuous use of fertilizers shovels the micronutrients and limits their availability in the grain and crop residues. These manures were prohibitively expensive to purchase to reap these long-term benefits of sustaining the soil health. But these amendments certainly have long lasting benefits on soil health. Similar results were also reported by Dadarwal et al. (2009).

3.3. Economic evaluation of mustard

The economic turnover of raising mustard exhibited considerable variation to the expedient of the residual effect of organic manures to the preceding maize in 2018-19 and the cumulative residual carried over effect for two years in 2018-19 and 2019-20 (Table 3).

3.3.1. Gross returns (₹ ha^{-1})

Higher gross returns was recorded with residual 75% RDN+25% N through farmyard manure (₹ 51,965 and ₹ 60,760 during 2018-19 and 2019-20 respectively) which was comparable with 75% RDN+25% N through poultry manure (₹ 51,405 and ₹ 60,428 during 2018–19 and 2019–20 respectively), 75% RDN+25% N through neem cake (₹ 50,664 and ₹ 58,602 during 2018–19 and 2019–20 respectively) 75% RDN+25% N through vermicompost (₹ 49,038 and ₹ 57,952 during 2018–19 and 2019–20 respectively) and 75% RDN+25% N through sheep manure (₹ 48,257 and ₹ 56,185 during 2018–19 and 2019–20 respectively) over residual 100% RDF, 75% RDN+*Azotobacter* at 5 kg ha^{-1}, 75% RDN+*Azospirillum* at 5 kg ha^{-1}, 75% RDN+*Azotobacter* at 2.5 kg ha^{-1}+*Azospirillum* at2.5 kg ha^{-1}.

Among subplot treatments, higher gross returns recorded with application of 100% RDF (₹ 55,762 and ₹ 64,028 during 2018–19 and 2019–20 respectively), which was comparable with 75% RDF (₹ 54,340 and ₹ 61,884 during 2018–19 and 2019–20 respectively) over 50% RDF and control.

3.3.2. Net returns (₹ ha^{-1})

Higher net returns recorded with residual 75% RDN+25% N through farmyard manure (₹ 28,488 and ₹ 37,283 during 2018–19 and 2019–20 respectively) which was comparable with 75% RDN+25% N through poultry manure (₹ 27,927 and ₹ 36,951 during 2018–19 and 2019–20 respectively), 75% RDN+25% N through neem cake (₹ 27,187 and ₹ 35,125 during 2018–19 and 2019–20 respectively) 75% RDN+25% N through vermicompost (₹ 25,560 and ₹ 34,475 during 2018–19 and 2019–20 respectively) over residual 75% RDN+25% N through sheep manure, 75% RDN+*Azotobacter* at 5 kg ha^{-1}, 75% RDN+*Azospirillum* at 5 kg ha^{-1}, 75% RDN+*Azotobacter* at 2.5 kg ha^{-1}+*Azospirillum* at 2.5 kg ha^{-1}. Lower net return was recorded with RDF (₹ 13,766 and ₹ 16,871 during 2018–19 and 2019–20 respectively),

Among subplot treatments, higher net returns recorded with application of 100% RDF (₹ 30,332 and ₹ 38,598 during 2018–19 and 2019–20 respectively), which was comparable with 75% RDF (₹ 30,030 and ₹ 37,574 during 2018–19 and 2019–20 respectively) over 50% RDF and control. These findings were in confirmation with Kumawat et al. (2014).

3.3.3. B:C ratio

More B:C ratio recorded with residual 75% RDN+25% N through farmyard manure (2.19 and 2.56 during 2018-19 and 2019-20 respectively) which was comparable with 75% RDN+25% N through poultry manure (2.16 and 2.55 during 2018–19 and 2019–20 respectively), 75% RDN+25% N through neem cake (2.13 and 2.47 during 2018–19 and 2019–20 respectively) 75% RDN+25% N through vermicompost (2.07 and 2.44 during 2018–19 and 2019–20 respectively) over residual 75% RDN+25% N through sheep manure, 75% RDN+*Azotobacter* at 5 kg ha^{-1}, 75% RDN+*Azospirillum* at 5 kg ha^{-1}, 75% RDN+*Azotobacter* at 2.5 kg ha^{-1}+*Azospirillum* at 2.5 kg ha^{-1}.

Among subplot treatments, more B:C ratio recorded with application of 75% RDF (2.24 and 2.55 during 2018–19 and 2019–20 respectively), which was comparable with 100% RDF (2.19 and 2.52 during 2018–19 and 2019–20 respectively) over 50% RDF and control.

The mustard crop grown after maize fertilized with the recommended level of 200:60:50 kg ha^{-1} NPK accrued relatively less gross and net returns ha^{-1}compared to the substitution of 25% nitrogenous fertilizer with organic manures. The benefit cost ratio was also low. The venture to invest ₹ 17,500 in 2018 and ₹ 16,250 in 2019 on farmyard manure to preceding maize was highly lucrative. It maximized the net returns to ₹ 28,488 and ₹ 37,283 ha^{-1} in the corresponding years. The B:C ratios were also maximized to 2.19 and 2.56 in the two years. The substitution of sheep manure was also equally effective if ₹ 2,400 on 1.4 t was affordable. In practice most farmers did not purchase these manures. They might tilt their preference to substitute 25% nitrogenous fertilizer with farmyard manure or sheep manure to the nutrient exhaustive maize crop especially in soils low in organic carbon and nitrogen to

Table 3: Economics of mustard in maize–mustard cropping system as influenced by direct and residual effects of different treatments

Treatments	Gross returns (₹ ha^{-1})			Net returns (₹ ha^{-1})			B:C ratio		
	2018–19	2019–20	Mean	2018–19	2019–20	Mean	2018–19	2019–20	Mean
Main plot treatments: (Residual effect) (M)									
M_1-100% RDF (200:60:50 kg ha^{-1} N: P: K)	37244	42348	39796	13766	18871	16319	1.57	1.78	1.68
M_2-75% RDN+25% N through FYM	51965	60760	56363	28488	37283	32886	2.19	2.56	2.38
M_3-75% RDN+25% N through VC	49038	57952	53495	25560	34475	30018	2.07	2.44	2.26
M_4-75% RDN+25% N through PM	51405	60428	55917	27927	36951	32439	2.16	2.55	2.36
M_5-75% RDN+25% N through SM	48257	56185	52221	24780	32707	28744	2.03	2.37	2.20
M_6-75% RDN+25% N through NC	50664	58602	54633	27187	35125	31156	2.13	2.47	2.30
M_7-75% RDN+Azotobacter at 5 kg ha^{-1}	39424	45156	42290	15946	21679	18813	1.66	1.90	1.78
M_8-75% RDN+Azospirillum at 5 kg ha^{-1}	40910	47328	44119	17433	23851	20642	1.72	2.00	1.86
M_9-75% RDN+Azotobacter at 2.5 kg ha^{-1}+ Azospirillum at 2.5 kg ha^{-1}	44084	49788	46936	20607	26311	23459	1.86	2.11	1.99
SEm±	963	1064		998	1036		0.04	0.05	
CD (p=0.05)	2913	3217		3016	3133		0.12	0.15	
Sub plot treatments: Direct effect (S)									
S_1- 0:0:0 kg ha^{-1} N: P: K (Control)	30097	35977	33037	9127	15007	12067	1.44	1.72	1.58
S_2-30: 20: 20 kg ha^{-1} NPK (50% RDF)	43353	50798	47076	20153	27598	23876	1.87	2.19	2.03
S_3- 45: 30: 30 kg ha^{-1} NPK (75% RDF)	54340	61884	58112	30030	37574	33802	2.24	2.55	2.40
S_4- 60: 40: 40 kg ha^{-1} NPK (100% RDF)	55762	64028	59895	30332	38598	34465	2.19	2.52	2.36
General Mean	45888	53172	49530	22410	29694	26052	1.93	2.24	2.09
SEm±	662	926		608	853		0.03	0.04	
CD (p=0.05)	1881	2633		1729	2424		0.07	0.10	
Interactions (S×M)									
SEm±	1927	2128		1995	2072		0.08	0.10	
CD (p=0.05)	NS	NS		NS	NS		NS	NS	
Interactions (M×S)									
SEm±	1970	2630		1869	2445		0.08	0.11	
CD (p=0.05)	NS	NS		NS	NS		NS	NS	

benefit substantial increase in yield of mustard raised in the following *rabi* season. Thereby they enjoy the pleasure of high income. The next option to the farmers who by chance do not have farmyard manure was to opt the poultry manure with relatively low expense of ₹ 6,800 ha^{-1}. This treatment was also almost equally profitable to farmyardmanure. The benefits to reap economically high profits by the integrated nitrogen management of maize through the residual tapping of fertilizers by mustard was also documented by Saha et al. (2010), Karforma et al. (2012), Gupta et al. (2014) and Mukherjee (2016). Mustard responded to maximize the net profit ha^{-1} (₹ 30,030 and ₹ 37,574 during 2018–19 and

2019–20 respectively) and benefit: cost ratios (₹ 2.24 and ₹ 2.55 during 2018–19 and 2019–20 respectively) to the 75% recommended level of 45:30:30 kg ha^{-1} NPK. Systematic reduction to 50% of the nutrient level reduced the income. In an earlier experiment, Panwar et al. (2008) reported that the substitution of 50% nitrogenous fertilizer with farmyard manure while applying the recommended level of fertilizers to mustard increased the net profit of maize-mustard cropping system.

3.4. Economic evaluation of maize-mustard cropping system

An economic evaluation of maize-mustard cropping system in response to the influence of nutrient management strategies is presented in Table 4.

3.4.1. Gross returns (₹ ha^{-1})

Higher gross returns recorded with residual 75% RDN+25% N through vermicompost (₹ 1,73,482 and ₹ 1,88,276 during 2018–19 and 2019–20 respectively) which was comparable with 75% RDN+25% N through farmyard manure (₹ 1,70,220 and ₹ 1,84,977 during 2018–19 and 2019–20 respectively), 75% RDN+25% N through poultry manure (₹ 1,57,244 and ₹ 1,71,599 during 2018–19 and 2019–20 respectively) and 75% RDN+25% N through sheep manure (₹ 1,55,106 and ₹ 1,68,871 during 2018–19 and 2019–20 respectively) over residual 100% RDF, 75% RDN+*Azotobacter* at 5 kg ha^{-1}, 75% RDN+*Azospirillum* at 5 kg ha^{-1}, 75% RDN+*Azotobacter* at 2.5 kg ha^{-1}+*Azospirillum* at 2.5 kg ha^{-1}. Lower gross return was recorded with 75% RDN+*Azotobacter* at 5 kg ha^{-1} (₹ 1,29,482 and ₹ 1,38,086 during 2018–19 and 2019–20 respectively).

Among subplot treatments, higher gross returns recorded with application of 100% RDF (₹ 1,62,890 and ₹ 1,75,771 during 2018–19 and 2019–20 respectively), which was comparable with 75% RDF (₹ 1,61,467 and ₹ 1,73,627 during 2018–19 and 2019–20 respectively) over 50% RDF and control.

3.4.2. Net returns (₹ ha^{-1})

Higher net returns recorded with residual 75% RDN+25% N through vermicompost (₹ 1,00,755 and ₹ 1,15,549 during 2018–19 and 2019–20 respectively) which was comparable with 75% RDN+25% N through farmyard manure (₹ 97,993 and ₹ 1,13,999 during 2018–19 and 2019–20 respectively) and 75% RDN+25% N through sheep manure (₹ 97,978 and ₹ 1,11,743 during 2018–19 and 2019–20 respectively) 75% RDN+25% N through poultry manure(₹ 95,716 and ₹ 1,10,072 during 2018–19 and 2019–20 respectively), 75% RDN+25% N through neem cake (₹ 89,776 and ₹ 1,02,405 during 2018–19 and 2019–20 respectively), over residual 75% RDN+*Azotobacter at* 5 kg ha^{-1}, 75% RDN+*Azospirillum* at 5 kg ha^{-1}, 75% RDN+*Azotobacter* at 2.5 kg ha^{-1}+*Azospirillum* at 2.5 kg ha^{-1}.

Among subplot treatments, significantly higher net returns was recorded with application of 100% RDF (₹ 1,00,049 and ₹1,13,068 during 2018–19 and 2019–20 respectively), which was comparable with 75% RDF (₹ 99,746 and ₹ 1,12,045 during 2018–19 and 2019–20 respectively) over 50% RDF and control.

3.4.3. B:C ratio

More B:C ratio recorded with residual 100% RDF (2.82 and 2.98 during 2018–19 and 2019–20 respectively) which was comparable with 75% RDN+25% N through sheep manure (2.71 and 2.95 during 2018–19 and 2019–20 respectively) 75% RDN+25% N through poultry manure (2.55 and 2.79 during 2018–19 and 2019–20 respectively), (2.38 and2.59 during 2018–19 and 2019–20 respectively) over residual 75% RDN+25% N through farmyard manure, 75% RDN +25% N through vermicompost, 75% RDN+25% N through neemcake, 75%RDN+*Azotobacter* at 5 kg ha^{-1}, 75% RDN+*Azospirillum* at 5 kg ha^{-1}, 75% RDN+*Azotobacter* at 2.5 kg ha^{-1}+*Azospirillum* at 2.5 kg ha^{-1}. Lower B:C ratio was recorded with 75% RDN+ *Azotobacter* at 5 kg ha^{-1} (2.35 and 2.51 during 2018–19 and 2019–20 respectively).

Among subplot treatments, more B:C ratio recorded with application of 75% RDF (2.63 and 2.83 during 2018–19 and 2019–20 respectively), which was comparable with 100% RDF 2.60 and 2.81 during 2018–19 and 2019–20 respectively) over 50% RDF and control. These results are in accordance with Kumawat et al. (2014) and Singh et al. (2011).

The impact of substituting 25% nitrogenous fertilizer to maize on the gross and net returns ha^{-1} as well as the benefit cost ratio was well confirmed in this investigation. The wary cost of organic manures did not appeal its adoption by the small and marginal farmers already in financial crisis. The results showed that all the organic manures tested in this investigation were highly productive and profitable. The consistent outliers were the farmyard manure and sheep manure during the two years. The recommended level of 200:60:50 kg ha^{-1} NPK to maize and 75% recommended level of fertilizers 45:30:30 kg ha^{-1} NPK to mustard was the ideal schedule to realize high gross returns of ₹ 1,66,495 in 2018 and ₹ 1,77,389 ha^{-1} in 2019. The net returns were ₹ 1,08,935 and ₹ 1,19,829 ha^{-1} with cost benefit ratios of 1.89 and 2.08 during the respective years. These benefits were realized with a total expense of ₹ 57,560 ha^{-1} each year. The substitution of 25% nitrogenous fertilizer to maize with bulky organic manures with low level of nutrients and high expenses buoyed the returns. This would not appeal the economically hard-hit farmers to afford huge expenses. But certainly, it was a practical endeavor to most farmers who insure their farms with 1or 2 cattle and/or few sheep. Maximum net returns of ₹ 1,06,137 ha^{-1} were realized by the substitution of 25% nitrogenous fertilizer to maize and applying the 75% recommended level of 45:30:30 kg ha^{-1} NPK to mustard in 2018. The income was ₹ 1,23,222 ha^{-1} in 2019. These benefits arrived to deem that ₹ 17,500 were spending on farmyard manure. In fact, the expense reduced by ₹ 620 on 50 kg urea as 25% substitution to the recommended level of 200 kg N ha^{-1}. Sheep manure was also equally remunerative. When substituted with 25% nitrogenous fertilizer to maize in *kharif* and fertilized mustard with 60:40:40 kg ha^{-1} NPK fetched a net gain of ₹ 1,06,953 in 2018 and ₹ 1,21,702 in 2019. Deemed that the

Table 4: Economics of maize–mustard cropping system as influenced by direct and residual effects of different treatments

Treatments	Gross returns (₹ ha^{-1})			Net returns (₹ ha^{-1})			B:C ratio		
	2018–19	2019–20	Mean	2018–19	2019–20	Mean	2018–19	2019–20	Mean
Main plot treatments: (Residual effect) (M)									
M_1-100% RDF (200:60:50 kg ha^{-1} N: P: K)	160034	169209	164622	103307	112482	107895	2.82	2.98	2.90
M_2-75% RDN+25% N through FYM	170220	184977	177599	97993	113999	105996	2.36	2.60	2.48
M_3-75% RDN+25% N through VC	173482	188276	180879	100755	115549	108152	2.38	2.59	2.49
M_4-75% RDN+25% N through PM	157244	171599	164422	95716	110072	102894	2.55	2.79	2.67
M_5-75% RDN+25% N through SM	155106	168871	161989	97978	111743	104861	2.71	2.95	2.83
M_6-75% RDN+25% N through NC	152504	165132	158818	89776	102405	96091	2.43	2.63	2.53
M_7-75% RDN+Azotobacter at 5 kg ha^{-1}	129482	138086	133784	74505	83108	78807	2.35	2.51	2.43
M_8-75% RDN+Azospirillum at 5 kg ha^{-1}	136516	146986	141751	81539	92008	86774	2.48	2.67	2.58
M_9-75% RDN+Azotobacter at 2.5 kg ha^{-1}+ Azospirillum at 2.5 kg ha^{-1}	142553	151098	146826	87575	96121	91848	2.59	2.75	2.67
SEm±	6288	5734		5833	5735		0.10	0.09	
CD (p=0.05)	19013	17339		17637	17341		0.29	0.28	
Sub plot treatments: Direct effect (S)									
S_1- 0:0:0 kg ha^{-1} N: P: K (Control)	137225	147720	142473	78844	89478	84161	2.36	2.55	2.46
S_2-30: 20: 20 kg ha^{-1} NPK (50% RDF)	150480	162541	156511	89869	102069	95969	2.49	2.69	2.59
S_3- 45: 30: 30 kg ha^{-1} NPK (75% RDF)	161467	173627	167547	99746	112045	105896	2.63	2.83	2.73
S4- 60: 40: 40 kg ha^{-1} NPK (100% RDF)	162890	175771	169331	100049	113068	106559	2.60	2.81	2.71
General Mean	153016	164915	158966	92127	104165	98146	2.52	2.72	2.46
SEm±	662	887		803	889		0.03	0.02	
CD (*p*=0.05)	1881	2522		2283	2528		0.09	0.06	
Interactions (S×M)									
SEm±	12575	11468		11665	11470		0.19	0.19	
CD (*p*=0.05)	NS	NS		NS	NS		NS	NS	
Interactions (M×S)									
SEm±	6518	6180		6195	6183		0.13	0.11	
CD (*p*=0.05)	NS	NS		NS	NS		NS	NS	

sheep manure worth ₹ 2,400 was purchased, the cultivation expenses inflated to ₹ 59,080 ha^{-1}. The cost of ₹ 620 on 50 kg urea was also low in this treatment. This result confirmed with the findings of Munda and Islam (2007).

The present-day slogan low cost more profit technologies aptly fit to the integrated nutrient management of maize with farm produced organic manures. The use of farmyard manure or sheep manure were the not only cost effective but more productive and highly profitable proposition. These manures were also a long-term insurance for soil health.

4. Conclusion

Integrated nutrient management with vermicompost, FYM, and sheep manure produced profits comparable to sole inorganic fertilization. Application of 200:60:50 kg ha^{-1} NPK recorded the highest net returns and benefit–cost ratio during both years. Partial substitution of inorganic nitrogen through organic manures reduced profitability per unit investment but maintained satisfactory absolute returns. Due to easy on-farm availability of manures, particularly FYM, integrated nutrient management remains a practical and sustainable approach for maintaining soil fertility and ensuring acceptable economic returns in crop production systems.

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