



Residual effect of INM on mungbean (*Vigna radiata*) growth, yield uptake and nutrient balance

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) season of 2019–20 and summer season of 2020–21 at Byrasandra village, Karnataka to study the residual effects of integrated nitrogen management (INM) in maize (*Zea mays* L.) on succeeding mungbean [*Vigna radiata* (L.) R. Wilczek] growth, yield, and soil properties. The residual effect of treatment involving 75% recommended dose of nitrogen (RDN) + 50% recommended dose of farmyard manure (RD FYM) + 25% RDN through vermicompost to *kharif* maize resulted in significant ($P < 0.05$) taller mungbean plants (25.4 cm), more leaves (16.0), increased pod count (21.7), longer pods (9.7 cm), higher test weight (4.4 g), seed yield (880.4 kg/ha) and haulm yield (1815.8 kg/ha) at harvest compared to the control group. After mungbean harvest, plots treated with 75% recommended dose of nitrogen (RDN) + 50% recommended dose of farmyard manure (RD FYM) + M 25% RDN through vermicompost showed significantly higher uptake of total N, total P, and total K (50.8, 9.3, and 49.1 kg/ha, respectively) compared to the control, improving soil nutrient balance and achieving the highest benefit-cost ratio in *Alfisols*.

Keywords: INM, Maize, Urban solid waste compost, Vermicompost

Mungbean [*Vigna radiata* (L.) R. Wilczek] is a vital pulse crop in India, known as the Golden Bean due to its high nutritional value (24.2% protein, 1.3% fat, 60.4% carbohydrate). It's a short-duration crop grown twice a year during *kharif* (June–October) and *rabi* (October–April), contributing 10% to India's pulse production with 2.5 million tonnes annually with a productivity of 548 kg/ha (Sindhi *et al.* 2016). It enriches soil fertility by adding 30 kg/ha/annum of nitrogen through symbiotic atmospheric N fixation and recorded 2.64 million tonnes of production in 2020–21 (Anonymous 2020). Understanding N transformation and bioavailability is crucial when using organic sources like farm yard manure, vermicompost, urban solid waste compost, and mineral fertilizers across cropping seasons. Organic sources exhibit a residual effect on subsequent seasons, with only 1/3 to 2/3 of added nutrients available in the first season (Singh *et al.* 2008, Singh and Ahlawat 2014). Thus, comprehending nitrogen transformation, fractionation, and crop uptake is vital for sustainable crop productivity and soil health. Scant information exists on the residual impact of growth and yield in the maize-mungbean sequence in Karnataka. This study investigates the residual effect of

integrated nitrogen management in maize on mungbean growth and yield parameters within the maize-mungbean cropping sequence.

MATERIALS AND METHODS

Field experiments were conducted during rainy (*kharif*) season of 2019–20 and summer season of 2020–21 at the same experimental site (farmers' fields) at Byrasandra village, Karnataka (13.3937° N, 77.8653° E). The soil samples were analysed by standard analytical procedures. The soil was sandy loam in nature, acidic (pH 5.8), electrical conductivity of 0.09 dS/m, organic carbon content of 5.2 g/kg with low nitrogen (254.3 kg N/ha), medium phosphorus (31.6 kg P₂O₅/ha), and medium potassium (191.3 kg K₂O/ha) content. Organic manures such as urban solid waste compost (USWC), vermicompost, Farmyard manure (FYM) were sourced from Karnataka Compost Development Corporation Ltd. (KCDC), Bengaluru, and Zonal Agricultural Research Station, University of Agricultural Sciences, Bengaluru (UASB).

Treatment details: The experiment used a randomized complete block design (RCBD) with 3 replications and 10 treatments. Treatments consisted of T₁, absolute control; T₂, RDF (100% NPK); T₃, RDF (100% NPK + FYM @ 10 t/ha); T₄, 75% RDN + 50% RD FYM + 25% RDN equivalent USWC; T₅, 50% RDN + 25% RD FYM + 50% RDN equivalent USWC; T₆, 75% RDN + 50% RD FYM

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+ 25% RDN equivalent vermicompost; T₇, 50% RDN + 25% RD FYM + 50% RDN equivalent vermicompost; T₈, 100% RDN equivalent USWC; T₉, 100% RDN equivalent vermicompost and T₁₀, 100% RDN equivalent FYM. Recommended P and K was common to T₂–T₁₀ treatments. RDF, recommended dose of fertilizers (RDF) for maize was 150:75:40 kg of N: P₂O₅:K₂O/ha and RD FYM was 10 t/ha. Maize hybrid MAH-14-5 was grown during *kharif* (October) 2019 and 2020 with 60 cm × 30 cm spacing, followed by mungbean as residual crop, variety KKM-3 during summer (February) 2020 and 2021 with 30 cm × 10 cm spacing, while maintaining the specified treatments.

Both crops were grown following package of practices (POP) of UASB and received protective irrigation. Hand weeding was performed at 25 and 45 days after sowing. Organic nitrogen sources like USWC, vermicompost, and FYM (with nitrogen content of 1.52%, 1.04%, and 0.56% on a dry weight basis) were added to the soil 15 days before sowing maize to meet the required quantity of N. Recommended dose doses of N, P₂O₅, and K₂O were supplied via urea, single super phosphate and muriate of potash. Growth and yield parameters were measured in randomly selected plants in each treatment. Above-ground biomass was separated into seeds and haulm, dried and weighed. Soil samples were collected before and after the experiment at a depth of 0–15 cm for chemical analysis. Input prices at the time of application were used and treatment wise cost of cultivation was worked. Net returns per hectare were determined by subtracting cultivation costs from gross income per hectare, and the benefit-cost ratio was computed using the following formula.

$$\text{Benefit : Cost} = \frac{\text{Gross returns (₹)}}{\text{Cost of cultivation (₹)}}$$

Statistical analysis: The study data was analysed as per the procedure given by Sundaraj *et al.* (1972) for randomised complete block design (RBD), and treatment differences were assessed using Duncan's Multiple Range test (DMRT).

RESULTS AND DISCUSSION

Effect of nitrogen management on plant height and number of leaves: Nitrogen management practices significantly affected mungbean growth parameters and the treatment T₆ (75% RDN + 50% RD FYM + 25% RDN through vermicompost) showed significantly ($P < 0.05$) higher plant height (13.5, 25.1, and 25.4 cm) and more leaves (14.6, 15.9, and 16.0) at 30, 45 DAS and harvest respectively, compared to other treatments, while the absolute control had lower plant height (8.53, 17.7 and 18.1 cm) and fewer leaves (9.0, 10.0, and 10.6) at 30, 45 DAS and harvest respectively (Table 1). This improvement likely resulted from organic manure and inorganic nitrogen, with nutrients released by previous maize crops benefiting mungbean growth (Barkha *et al.* 2020). Typically, 40–50% of nutrients from organic manure are used by the first crop, with the rest benefitting subsequent crops (Sindhi *et al.* 2016). The residual effect of 75% RDN + 50% RD FYM + 25% RDN via vermicompost

and USWC increased plant height and leaf count. This was due to increased nutrient availability upon mineralization and uptake of major and micronutrients as seen in prior studies with FYM and chemical fertilizers in previous sorghum crop enhancing mungbean seed yield Kuligod *et al.* (2011). Patel *et al.* (2017) also found a significant residual effect when using 75% RDN from chemical fertilizer + 25% RDN from vermicompost in finger millet for succeeding mungbean crop.

Effect of N management on yield parameters, seed and haulm yield of mungbean: The residual effect of treatment T₆ significantly ($P < 0.05$) increases the yield parameters such as number of pods per plant (21.7), pod length (9.7 cm) and test weight (4.4 g) compared to other treatments, except for T₄ (21.7, 9.4 and 4.3, respectively), T₃ (21.3, 9.0 and 4.3, respectively), T₇ (20.8, 9.0 and 4.2, respectively). The absolute control had significantly ($P < 0.05$) lower values. The increase in yield parameters reflects the benefit of combining organic and inorganic nutrient sources, likely due to improved growth attributes (Table 1) and enhanced nutrient uptake (Table 2). Differential residual effects of organic manures on mungbean yield attributes are linked to variations in their nutrient quality and quantity. Similar findings were reported by Rostami *et al.* (2012) for the residual effect of INM practices in crop sequence. In a two-year crop sequence (2020 and 2021), mungbean seed yield (880.4 kg/ha) was significantly higher with the residual effect of treatment T₆ compared to other treatments. The lowest seed yield was recorded in T₁ (630.3 kg/ha). Treatment T₆ showed highest haulm yield (1815.8 kg/ha), followed closely by T₄ (1687.0 kg/ha). Control treatment T₁ had the lowest haulm yield (1346.5 kg/ha) (Table 1).

Crop yield is influenced by climate, nutrient availability, soil properties, agronomic practices, and genetic potential (Vigneshvarraj *et al.* 2020). The increase in seed and haulm yield of succeeding mungbean was due to organic manure and inorganic nutrients may be linked to improved growth and yield parameters (Table 1). Enhanced nutrient uptake from nutrient-rich soil after a previous maize crop led to improved growth and yield parameters. Approximately two-thirds of the organic manure nutrients were utilized by the maize crop, with the remaining one-third likely mineralizing and becoming available for subsequent crops. This aligns with findings of Sindhi *et al.* (2016) emphasizing the prolonged nutrient release from organic manure, evident in our study with higher soil labile N and organic N fractions post-maize harvest. Thesiya *et al.* (2019) reported slow nutrient release from vermicompost boosted cowpea yield via residual effects, attributed to differences in organic sources' mineralization rates due to C: N ratios and nutrient quantities. This aligns with Patel *et al.* (2017), who found a significant residual effect when applying 75% RDN via chemical fertilizer + 25% RDN via vermicompost to finger millet for succeeding mungbean crops. Joseph *et al.* (2018) reported the highest grain and haulm yields (952.0 and 2638.8 kg/ha, respectively) with 50% RDF + 10 t FYM/ha for succeeding mungbean. Arun and Thippeshapa (2020)

Table 1 Effect of nitrogen management on growth, yield parameters, seed and haulm yield of mungbean

Treatment	Plant height (cm)			No. of leaves			No. of pods per plant	Pod length (cm)	Test weight (g)	Seed yield (kg/ha)	Haulm yield (kg/ha)
	30 DAS	45 DAS	At harvest	30 DAS	45 DAS	At harvest					
T ₁	8.5 ^c	17.7 ^d	18.1 ^c	9.0 ^d	10.0 ^e	10.6 ^f	14.5 ^c	6.5 ^f	3.9 ^c	630.3 ^e	1346.5 ^c
T ₂	9.2 ^c	20.0 ^{cd}	20.6 ^{bc}	10.3 ^d	12.3 ^d	12.4 ^e	16.3 ^c	7.0 ^{ef}	4.1 ^{bc}	730.7 ^{cde}	1461.7 ^{bc}
T ₃	12.0 ^b	24.0 ^{ab}	24.5 ^a	14.0 ^{ab}	15.2 ^{ab}	15.5 ^{ab}	21.3 ^{ab}	9.0 ^{abc}	4.3 ^{ab}	837.4 ^{abc}	1649.5 ^{ab}
T ₄	11.9 ^b	23.7 ^{ab}	24.5 ^a	13.7 ^{ab}	15.4 ^{ab}	15.6 ^a	21.7 ^a	9.4 ^{ab}	4.3 ^{ab}	852.1 ^{ab}	1687.0 ^{ab}
T ₅	11.6 ^b	22.5 ^{abc}	23.5 ^{ab}	12.3 ^{bc}	14.5 ^{abc}	14.5 ^{abcd}	20.4 ^{ab}	8.5 ^{bcd}	4.2 ^b	800.2 ^{abcd}	1634.2 ^{ab}
T ₆	13.5 ^a	25.1 ^a	25.4 ^a	14.6 ^a	15.9 ^a	16.0 ^a	21.7 ^a	9.7 ^a	4.4 ^a	880.4 ^a	1815.8 ^a
T ₇	12.0 ^b	22.9 ^{abc}	24.2 ^a	12.8 ^{bc}	14.7 ^{abc}	14.7 ^{abc}	20.8 ^{ab}	9.0 ^{abc}	4.2 ^{ab}	780.1 ^{abcd}	1631.9 ^{ab}
T ₈	11.6 ^b	22.7 ^{abc}	23.0 ^{ab}	12.3 ^{bc}	13.0 ^{cd}	13.0 ^c	19.2 ^{ab}	8.0 ^{cde}	4.2 ^b	739.5 ^{cd}	1533.4 ^{bc}
T ₉	11.3 ^b	23.0 ^{abc}	23.5 ^{ab}	12.6 ^{bc}	13.5 ^{bcd}	13.6 ^{cde}	19.9 ^{ab}	8.4 ^{bcd}	4.2 ^b	758.0 ^{bcd}	1591.6 ^{ab}
T ₁₀	10.8 ^b	21.8 ^{bc}	22.3 ^{ab}	11.9 ^e	12.2 ^d	12.7 ^{bcde}	18.9 ^b	7.5 ^{def}	4.1 ^{bc}	704.3 ^{de}	1502.4 ^{bc}
SEm	0.4	0.9	0.9	0.5	0.5	0.5 ^{de}	0.7	0.3	0.1	25.2	50.8
CD at 5%	1.3	2.6	2.7	1.4	1.5	1.6	2.2	1.0	0.1	72.3	145.6

Data followed by different letters within a column are significantly different based on Duncan's Multiple Range test (DMRT) test at 5% significance level. Treatment details are given under Materials and Methods.

also observed higher mungbean seed and haulm yields when using CS-biochar at 8 t/ha and 10 t/ha FYM with RDF.

Effect of nitrogen management on total NPK uptake (kg/ha) by mungbean: Mungbean had significantly ($P < 0.05$) higher seed yield, haulm yield and total uptake of nitrogen (35.3, 15.5, and 50.8 kg/ha, respectively), phosphorus (4.2, 5.1, and 9.3 kg/ha, respectively), and potassium (15.0, 34.1 and 49.1 kg/ha, respectively) due to residual effect of T₆ treatment (35.3, 4.2, 15.0 for N; 15.5, 5.1, 34.1 for P; 50.8, 9.3, 49.1 for K) compared to all other treatments. Conversely, treatment T₁ had significantly ($P < 0.05$) lower nutrient uptake (N uptake: 19.7, 6.0 and 25.8 kg/ha; P uptake: 1.5, 1.2 and 2.8 kg/ha and K uptake: 7.3, 16.6 and 24.0 kg/ha, respectively). The increased nutrient uptake

in mungbean with T₆ was attributed to the residual effect resulting in improved growth and yield. The increased nutrient uptake in mungbean was due to the combined effect of organic and inorganic sources, enhancing nutrient release and promoting growth and yield (Barkha *et al.* 2020). Similar results were observed by Arun and Thippeshapa (2020) with FYM application, especially when combined with fertilizers. Warman and Termeer (2005) found higher phosphorus uptake with vermicompost application, and increased potassium uptake was attributed to the rich potassium content in compost, leading to greater crop absorption. The increased K uptake is attributed to the high compost K content, leading to greater plant K absorption due to the residual effect of USWC and vermicompost.

Table 2 Effect of nitrogen management on uptake of major nutrients by mungbean

Treatment	Total N uptake (kg/ha)			Total P uptake (kg/ha)			Total K uptake (kg/ha)		
	Seed	Haulm	Total	Seed	Haulm	Total	Seed	Haulm	Total
T ₁	19.7 ^g	6.0 ^g	25.8 ^f	1.5 ^g	1.2 ^g	2.8 ^g	7.3 ^g	16.6 ^e	24.0 ^e
T ₂	25.3 ^{ef}	8.8 ^f	34.2 ^e	2.2 ^f	2.3 ^f	4.5 ^f	9.0 ^f	19.2 ^e	28.2 ^e
T ₃	31.4 ^{bc}	12.9 ^{bc}	44.4 ^{bc}	3.5 ^b	3.9 ^{cd}	7.5 ^{bc}	13.2 ^b	28.5 ^{bc}	41.7 ^{bc}
T ₄	32.4 ^{ab}	14.1 ^{ab}	46.6 ^{ab}	3.8 ^b	4.4 ^b	8.2 ^b	13.8 ^{ab}	29.9 ^b	43.8 ^b
T ₅	29.3 ^{bcd}	11.9 ^{cd}	41.2 ^{cd}	3.2 ^c	3.7 ^{de}	6.9 ^{cd}	12.6 ^{bc}	28.3 ^{bc}	41.0 ^{bc}
T ₆	35.3 ^a	15.5 ^a	50.8 ^a	4.2 ^a	5.1 ^a	9.3 ^a	15.0 ^a	34.1 ^a	49.1 ^a
T ₇	30.0 ^{bcd}	12.6 ^c	42.6 ^{bcd}	3.1 ^c	4.3 ^{bc}	7.5 ^{bc}	12.4 ^{bc}	29.4 ^b	41.9 ^{bc}
T ₈	27.2 ^{def}	10.8 ^{de}	38.1 ^{de}	2.7 ^{de}	2.7 ^f	5.5 ^e	10.5 ^{de}	25.3 ^{cd}	35.9 ^d
T ₉	28.6 ^{cde}	11.8 ^{cd}	40.4 ^{cd}	3.0 ^{cd}	3.4 ^e	6.5 ^d	11.2 ^{cd}	27.2 ^{bcd}	38.4 ^{cd}
T ₁₀	24.6 ^f	10.2 ^e	34.9 ^e	2.5 ^{ef}	2.4 ^f	4.9 ^{ef}	9.6 ^{ef}	23.9 ^d	33.6 ^d
SEm	2.0	0.8	2.8	0.2	0.2	0.4	0.8	1.8	2.6
CD at 5%	5.7	2.2	8.0	0.6	0.6	1.3	2.3	5.2	7.5

Treatment details are given under Materials and Methods.

Nutrient balance in soil at the end of the cropping system: Incorporating INM practices into the maize-mungbean system led to positive effects on soil nitrogen levels. The T₆ treatment resulted in the highest N uptake (50.8 kg/ha) and significantly increased available N (216.5 kg/ha) in the soil. This treatment also yielded the maximum net gain in nitrogen status in soil (10.3 kg/ha), outperforming others. Additionally, T₆ exhibited superior total phosphorus uptake (9.3 kg/ha) and the highest net gain in phosphorus (7.4 kg/ha), while T₇ had the lowest net gain (1.2 kg/ha).

For potassium balance, T₆ again excelled with the highest total potassium uptake (49.1 kg/ha) and maximum net gain (23.4 kg/ha), whereas T₂ had the lowest net gain (7.1 kg/ha) (Table 3). The application of integrated N sources from inorganic fertilizers, vermicompost and FYM over their initial status significantly increased soil nitrogen content, likely due to nitrogen mineralization and microbial activity which converts organically bound nitrogen into an available form. Nodule formation in mungbean also contributed to nitrogen availability.

Table 3 Balance for N, P₂O₅ and K₂O (kg/ha) in soil as influenced by integrated N management on succeeding mungbean crop

Treatments	Initial available N, P ₂ O ₅ and K ₂ O	Addition through fertilizer	Total	Removal by crops	Expected balance	Actual balance	Net loss (-) or gain (+)
*(1)	*(2)	*(3)	*(4=2+3)	*(5)	*(6=4-5)	*(7)	*(8=7-6)
<i>Nitrogen</i>							
T ₁	175.7	0.0	175.7	25.8	149.9	157.4	7.4
T ₂	214.1	0.0	214.1	34.2	179.9	189.3	9.3
T ₃	245.7	0.0	245.7	44.4	201.3	201.3	-0.0
T ₄	252.2	0.0	252.2	46.6	205.5	208.0	2.5
T ₅	240.0	0.0	240.0	41.2	198.7	193.7	-5.0
T ₆	257.0	0.0	257.0	50.8	206.1	216.5	10.3
T ₇	242.6	0.0	242.6	42.6	199.9	197.9	-1.9
T ₈	228.2	0.0	228.2	38.1	190.1	185.8	-4.2
T ₉	232.1	0.0	232.1	40.4	191.7	192.3	0.6
T ₁₀	226.0	0.0	226.0	34.9	191.1	184.1	-7.0
<i>Phosphorus</i>							
T ₁	20.5	0.0	20.5	2.8	17.7	19.0	1.2
T ₂	29.8	0.0	29.8	4.5	25.3	27.9	2.5
T ₃	34.5	0.0	34.5	7.5	26.9	30.6	3.7
T ₄	40.7	0.0	40.7	8.2	32.4	36.9	4.5
T ₅	43.2	0.0	43.2	6.9	36.2	38.4	2.1
T ₆	47.0	0.0	47.0	9.3	37.6	45.1	7.4
T ₇	51.9	0.0	51.9	7.5	44.4	45.6	1.2
T ₈	38.7	0.0	38.7	5.5	33.2	35.6	2.4
T ₉	41.3	0.0	41.3	6.5	34.8	39.1	4.2
T ₁₀	35.5	0.0	35.5	4.9	30.5	32.7	2.1
<i>Potassium</i>							
T ₁	115.2	0.0	115.2	24.0	91.2	102.4	11.2
T ₂	142.1	0.0	142.1	28.2	113.9	121.0	7.1
T ₃	148.3	0.0	148.3	41.7	106.5	127.0	20.4
T ₄	152.7	0.0	152.7	43.8	108.9	131.0	22.1
T ₅	159.4	0.0	159.4	41.0	118.4	132.1	13.6
T ₆	161.6	0.0	161.6	49.1	112.5	135.9	23.4
T ₇	169.2	0.0	169.2	41.9	127.3	137.0	9.7
T ₈	147.8	0.0	147.8	35.9	111.9	128.9	17.0
T ₉	150.	0.0	150.9	38.4	112.4	132.0	19.6
T ₁₀	145.3	0.0	145.3	33.6	111.7	125.3	13.6

Treatment details are given under Materials and Methods.

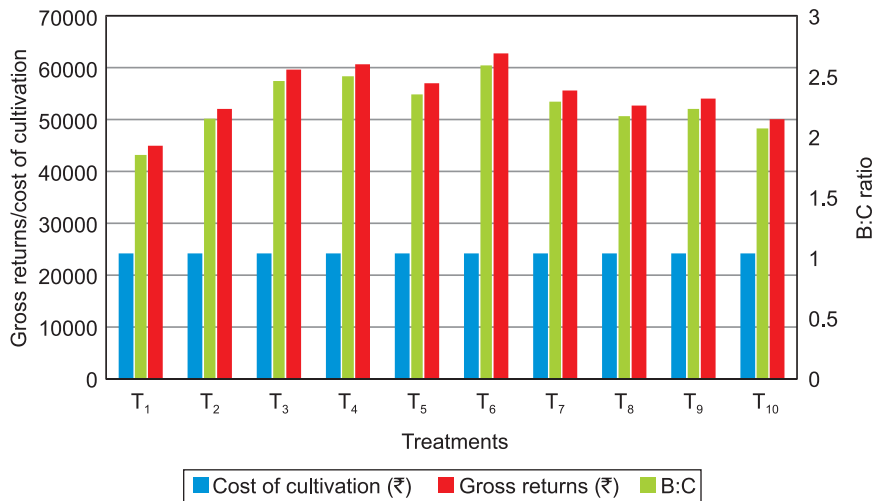


Fig 1 Economics (mean of 2020 and 2021) of succeeding mungbean production as influenced by N management practices.

Similarly, higher phosphorus and potassium available resulted from combining organic and inorganic nutrient sources, enhancing nutrient synchronization for maize and improving overall crop performance and nitrogen utilization for mungbean. Balasubramanian *et al.* (2016) found that a combination of 75% RDN through fertilizer and 25% vermicompost significantly boosted black gram growth, yield, and NPK uptake. INM practices improved microbial activity, enhancing nutrient availability in the soil (Katkar *et al.* 2011). Similarly, preceding application of 50% RDF + 50% RDN through FYM to rice and succeeding application of 75% RDF + Rhizobium + phosphate solubilizing bacteria (PSB) to mungbean increased growth and yield parameters of mungbean. Furthermore, INM adoption also positively impacted post-harvest soil nutrient balance (Mangaraj *et al.* 2022).

Economics of succeeding mungbean production as influenced by N management practices: Since mungbean was grown as residual crop its cost of cultivation was similar across plots, with T₆ yielding the highest gross returns (₹62723) and the lowest returns in T₁ (₹44933) (Fig 1). Net returns were highest in T₆ (₹38529) while T₁ had the lowest net returns (₹20739) (Fig 1). The treatment which received 75% RDN + 50% RD FYM + 25% RDN equivalent vermicompost (T₆) had the highest B:C ratio (2.59), followed by T₄ and T₃, whereas T₁ had the lowest B:C ratio (1.85) (Fig 1). This difference in B:C ratio was mainly due to the use of organic nutrients, which improved soil health and boosted crop productivity. These results align with previous research by Muniswamy *et al.* (2018) who reported that applying 25 kg N/ha + 40 kg S/ha + 0.1% zinc resulted in a maximum B:C ratio (2.3) for mungbean, while Preeti *et al.* (2017) found the highest B:C ratio (2.65) with the treatment N₃ (20:60:20 NPK) + 0.2% foliar spray of borax at 35 DAS for mungbean.

Based on the experimental research through the INM approach optimum dose of inorganics and organics. Combining 75% RDN + 50% RD FYM + 25% RDN

through vermicompost and USWC with chemical fertilizers enhanced mungbean growth and yield, with higher nutrient uptake and positive residual effects on soil nutrient balance, highlighting the importance of integrated nutrient management for mungbean production.

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