



Yield versus quality: Unravelling the nitrogen source trade-off in baby corn production

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Abstract

An experiment was conducted during summer 2026 at the Eastern Block of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, to study the effects of different organic nitrogen sources combined with inorganic fertiliser on the growth, yield and quality of baby corn. The experiment was laid out in a factorial randomised block design (FRBD) with two factors: organic sources (S₁- poultry manure, S₂- vermicompost, S₃- pig manure, S₄- goat manure) and organic-inorganic ratio of recommended dose of nitrogen (RDN) (R₁-50 : 50, R₂- 25 : 75). Three additional treatments (C₁- 100 % RDN through organic manure, C₂- 100 % RDN through inorganic fertiliser and C₃- absolute control) were included outside the factorial structure and compared with treatment combinations using Dunnett's test. Results revealed that the use of vermicompost significantly increased soil plant analysis development (SPAD) value (46.4), root length (52.5 cm), dry matter (95.0 g plant⁻¹), baby corn yield (12642 kg ha⁻¹) and green fodder yield (28326 kg ha⁻¹) compared with the other sources. The percentage of baby corn yield and green fodder yield over absolute control were 148.6 % and 121.3 %, respectively. Between the two ratios, 25 % RDN through organic source recorded greater plant height, dry matter and baby corn yield, while 50 % RDN recorded higher ascorbic acid (32.9 mg 100 g⁻¹) and total soluble solids (6.6 °Brix). These results indicate that vermicompost combined with inorganic fertiliser, particularly with 25 % of RDN supplied through vermicompost, can enhance the growth and yield of baby corn, whereas the 50 : 50 ratio may favour selected quality attributes, suggesting that integrated nutrient management practices can be adapted to specific production objectives in baby corn.

Keywords: goat manure; integrated nutrient management; pig manure; poultry manure; vermicompost; *Zea mays*

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1. Introduction

Maize (*Zea mays* L.) is one of the world's major cereal crops, surpassed only by rice and wheat and has earned the name "Queen of Cereals" owing to its extraordinary versatility (1). As per the 2025–26 second advance estimates, maize in India is cultivated over 128.4 lakh hectares, producing 461.5 lakh tonnes with a productivity of 3595 kg ha⁻¹ (2). States with major maize cultivation include Madhya Pradesh, Maharashtra and Karnataka. Traditionally, maize was cultivated as a food grain and fodder crop, but in recent decades it has become a high-value vegetable crop, most notably as sweet corn and baby corn. The cultivation of baby corn and sweet corn offers greater economic returns and improved market opportunities, thereby enhancing the profitability of maize-based cropping systems (3). Amongst these value-added products, baby corn is the youngest and immature ear of maize picked 2 or 3 days after silk emergence, usually 50–55 days after sowing, before the ear reaches the stage

of fertilisation (4). The marketable ear is 10–12 cm long and 1.0–1.5 cm in diameter and is characterised by its tender, crisp texture, mild sweetness and evenly spaced kernel rows (5). Baby corn is a good nutritional source of crude protein, dietary fibre, phosphorus, potassium, calcium and vitamin C (ascorbic acid). According to previous studies, moisture, protein, fat, ash and crude fibre in baby corn are 90.03, 17.96, 2.13, 5.30 and 5.89 % respectively on a dry weight basis (6).

Maize has relatively high nutrient requirements and responds strongly to balanced nutrient management. To achieve higher production, farmers apply large amounts of nitrogen, phosphorus and potassium (NPK)-based straight fertilisers, which leads to poor soil health. Among the major nutrients, N is highly soluble and very difficult to manage in the soil system. Therefore, proper N management in cropping systems is the need of the hour for sustainable production. Earlier studies also confirm that long-term intensive cropping without the addition of

organic manures declines soil quality and crop productivity (7). Nitrogen use efficiency can be increased through integrated use of organic and inorganic N sources. Application of organic manures not only supply essential nutrients but also improves various soil physical, chemical and biological properties (8). Therefore, a proper nutrient management strategy that combines organic and inorganic nutrient sources needs to be developed to sustain soil health and productivity.

Despite the growing body of literature on nutrient management in baby corn, most of the investigations have concentrated on a single manure type or a fixed organic-inorganic ratio, leaving the comparative performance of diverse organic manure sources at varying organic-inorganic proportions largely unexplored. This represents an important knowledge gap that limits the development of location-specific, evidence-based nutrient management recommendations for baby corn in Tamil Nadu. The present study was therefore undertaken to evaluate four organic nutrient sources such as poultry manure, pig manure, goat manure, vermicompost and farm yard manure (FYM) combined with inorganic fertilisers at two ratios (50 : 50 and 25 : 75 organic : inorganic recommended dose of nitrogen (RDN)), on the hypothesis that both the choice of organic source and its proportion relative to inorganic N would influence the growth, yield and quality outcomes in baby corn.

2. Materials and Methods

Experimental site

The present investigation was conducted during the summer season of 2026 at the Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. The experimental site is located at 11° N latitude and 76°56' E longitude at an altitude of 426.7 m above mean sea level and falls under the Western Agro-Climatic Zone of Tamil Nadu. The weather conditions prevailing during the crop growth period were characterised by a mean maximum temperature of 34.8 °C and a mean minimum temperature of 21.9 °C. The mean relative humidity was 82.8 % in the morning and 37.6 % in the evening. The crop received a mean wind speed of 5.4 km hr⁻¹ and a mean sunshine duration of 8.3 hr day⁻¹. Total rainfall recorded during the cropping period was 21.4 mm and mean solar radiation was 304.4 cal cm⁻² day⁻¹. Prior to the experiment, soil samples were collected from a depth of 0–15 cm and analysed for their initial physico-chemical properties. The soil of the experimental field is sandy clay loam in texture, with a pH of 8.6 and an electrical conductivity (EC) of 0.28 dS m⁻¹. Initial soil analysis revealed available N (alkaline potassium permanganate method), Olsen-extractable P and neutral normal ammonium acetate-extractable potassium levels of 280, 20 and 350 kg ha⁻¹ (expressed as elemental N, P and K), respectively. Based on the fertility rating limits of previous studies for N and for P and K, the experimental soil fell in the medium category for available N and P and high for available K (9, 10).

Experimental design and treatments

The experiment was laid out in a factorial randomised block design (FRBD) with two factors: Factor S, organic sources at 4 level (S₁ - poultry manure, S₂ - vermicompost, S₃ - pig manure, S₄ - goat manure) and factor R, two ratios of organic-inorganic source of RDN (R₁ – 50 : 50 and R₂ – 25 : 75), resulting in eight factorial treatment combinations (4 × 2). In addition, three control treatments (C₁ - 100 % RDN through organic manure (FYM at 14.5 t ha⁻¹ as basal and vermicompost at 5 t ha⁻¹ as top dressing on 25 days after sowing (DAS)), C₂ - 100 % RDN through inorganic fertiliser and C₃ - absolute control) were included outside the factorial structure, since they do not correspond to any single Factor S × Factor R combination (C₂, for instance, combines two organic sources rather than one). This gave eleven treatments (T₁–T₈ and C₁–C₃) in total, replicated thrice (Table 1). Data were analysed in two stages: a factorial ANOVA for the eight S × R combinations (main and interaction effects) and Dunnett's test comparing each factorial combination against C₁, C₂ and C₃ separately. The recommended fertiliser dose (RDF) for baby corn was 150 : 60 : 40 kg N : P₂O₅ : K₂O ha⁻¹.

Nutrient analysis of organic manures

The nutrient composition of the organic manures used in the experiment is presented in Table 2 and was determined prior to application. Nitrogen, P₂O₅ and K₂O contents were analysed using the Micro-Kjeldahl method (11), Vanadomolybdic yellow colour method and Flame Photometric method (11), respectively.

Land preparation and nutrient management

The field was initially ploughed using a tractor-drawn disc plough to break the compact soil layers, followed by a cultivator and rotavator to enhance the soil tilth. Ridges and furrows were formed before sowing. The quantities of individual organic manures required for each treatment were calculated based on their analysed total N concentrations to supply the designated proportion of the RDN on a total N-equivalent basis (Table 3). No N availability or mineralisation coefficient was applied in calculating the quantities of organic manures; therefore, the stated proportion of N supplied through organic sources refers to the total N applied rather than the immediately plant-available N. The quantity of organic manure required was calculated using the following formula:

$$\text{Quantity of organic manure (kg ha}^{-1}\text{)} = \frac{\text{Required N through organic source (kg ha}^{-1}\text{)}}{\text{Total N concentration of organic manure (\%)}} \times 100$$

For example, under T₁, where 50 % of the RDN (150 kg N ha⁻¹) was supplied through poultry manure, the required N contribution from poultry manure was 75 kg N ha⁻¹. Based on the analysed total N concentration of poultry manure (3.46 %), the quantity required was calculated as:

$$\frac{75 \times 100}{3.46} = 2167 \text{ kg ha}^{-1}$$



Table 1. Treatment details

Treatment Combinations		Treatment details
T ₁	S ₁ × R ₁	50 % RDN through poultry manure (2.17 t ha ⁻¹ as basal) + 50 % RDN through inorganic fertiliser
T ₂	S ₂ × R ₁	50 % RDN through vermicompost (8.24 t ha ⁻¹ as basal) + 50 % RDN through inorganic fertiliser
T ₃	S ₃ × R ₁	50 % RDN through pig manure (7.81 t ha ⁻¹ as basal) + 50 % RDN through inorganic fertiliser
T ₄	S ₄ × R ₁	50 % RDN through goat manure (7.35 t ha ⁻¹ as basal) + 50 % RDN through inorganic fertiliser
T ₅	S ₁ × R ₂	25 % RDN through poultry manure (1.08 t ha ⁻¹ as basal) + 75 % RDN through inorganic fertiliser
T ₆	S ₂ × R ₂	25 % RDN through vermicompost (4.12 t ha ⁻¹ as basal) + 75 % RDN through inorganic fertiliser
T ₇	S ₃ × R ₂	25 % RDN through pig manure (3.91 t ha ⁻¹ as basal) + 75 % RDN through inorganic fertiliser
T ₈	S ₄ × R ₂	25 % RDN through goat manure (3.68 t ha ⁻¹ as basal) + 75 % RDN through inorganic fertiliser
C ₁		100 % RDN through organic manure (FYM at 14.5 t ha ⁻¹ as basal and vermicompost at 5 t ha ⁻¹ as top dressing on 25 DAS)
C ₂		100 % RDN through inorganic fertiliser
C ₃		Absolute control (no organic and inorganic nutrient)

RDN: recommended dose of nitrogen; S₁: poultry manure; S₂: vermicompost; S₃: pig manure; S₄: goat manure; R₁: 50 % RDN through organic manure + 50 % RDN through inorganic fertiliser; R₂: 25 % RDN through organic manure + 75 % RDN through inorganic fertiliser; DAS: days after sowing; FYM: farmyard manure.

Table 2. Nutrient content of organic manures

Manure	N %	P ₂ O ₅ %	K ₂ O %
Poultry manure	3.46	1.60	1.60
Vermicompost	0.92	0.39	0.72
Pig manure	0.96	1.02	0.68
Goat manure	1.01	0.82	1.99
FYM	0.72	0.32	0.80

N: nitrogen; P₂O₅: phosphorus pentoxide; K₂O: potassium oxide; FYM: farmyard manure.

Table 3. Nutrient contribution from organic and inorganic sources under different nutrient-management treatments (kg ha⁻¹)

Treatment	N (kg ha ⁻¹)			P ₂ O ₅ (kg ha ⁻¹)			K ₂ O (kg ha ⁻¹)		
	Organic	Inorganic	Total	Organic	Inorganic	Total	Organic	Inorganic	Total
T ₁	75.08	74.98	150.06	34.72	25.28	60	34.72	5.28	40
T ₂	75.81	74.98	150.79	32.14	27.86	60	59.33	-	59.33
T ₃	74.98	74.98	149.96	79.66	-	79.66	53.11	-	53.11
T ₄	74.23	74.98	149.21	60.27	-	60.27	146.26	-	146.26
T ₅	37.37	112.5	149.87	17.28	42.72	60	17.28	22.72	40
T ₆	37.9	112.5	150.4	16.07	43.93	60	29.66	10.34	40
T ₇	37.54	112.5	150.04	39.88	20.12	60	26.59	13.41	40
T ₈	37.17	112.5	149.67	30.18	29.82	60	73.23	-	73.23
C ₁	150.40	-	150.4	65.90	-	65.9	152.00	-	152
C ₂	-	150	150	-	60	60	-	40	40
C ₃	-	-	0	-	-	0	-	-	0

N: nitrogen; P₂O₅: phosphorus pentoxide; K₂O: potassium oxide.

Thus, approximately 2.17 t poultry manure ha⁻¹ was applied under T₁. The same procedure was followed for calculating the quantities of other organic manures used in the respective treatments.

Organic manures were applied as basal and incorporated thoroughly into the soil 15 days before sowing. The quantities of P₂O₅ and K₂O supplied through organic manures were considered and the balance requirement was met through inorganic sources, namely single superphosphate (SSP) and muriate of potash (MOP), respectively. For nitrogen, 50 % of the calculated inorganic dose was applied as basal using urea, along with the entire calculated dose of SSP and MOP. The remaining 50 % N was top-dressed at 25 DAS.

Crop details and sowing

Baby corn hybrid G5417 was used for the study. The seeds were procured from Syngenta through the Consolidated Trading Company, Coimbatore. Sowing was carried out manually on ridges at a spacing of 45 × 20 cm with two seeds per hill at a depth of 3–4 cm. The experiment was laid out with a gross plot size of 3.6 m × 4 m and a net plot size of 2.7 m × 3.2 m. Gap filling was done at 7 DAS, followed by thinning at 14 DAS, maintaining 1 seedling per hill with a population of 11111 plants ha⁻¹. All recommended agronomic practices were followed uniformly for all treatments throughout the crop growth period. Irrigation was provided through drip irrigation using drippers of 8 L hr⁻¹ discharge capacity and irrigation was scheduled at a 3-day interval throughout the crop growth period. Weeds were managed by two hand weeding at 20 and 40 DAS. Plant protection was ensured through weekly spraying of neem oil and neem seed kernel extract (NSKE) against insect pests.

Plant sampling and analysis

Five healthy plants were randomly selected from each plot and tagged to record observations of plant height and chlorophyll content at 15 DAS, 30 DAS, 45 DAS and at harvest. The plant height was measured from the base to the tip of the longest leaf and was expressed in cm. Chlorophyll content was estimated using a soil plant analysis development (SPAD) chlorophyll meter (Konica Minolta, Japan). For root studies, 3 plants were randomly selected from the net plot area, carefully uprooted and cleaned and their root length was measured. The same uprooted plants were then oven-dried at 60 °C until a constant weight was attained. The mean dry weight was expressed as g plant⁻¹. Baby corn was harvested three days after silk emergence. A total of 4 pickings were carried out at 2- or 3-day intervals based on silk emergence, with harvesting done during the morning hours. Baby corn cobs with husk intact were harvested plot-wise in the morning and weighed, expressed as kg ha⁻¹. After the final picking, plants from the net plot area were harvested, weighed plot-wise and green fodder yield was recorded and expressed in kg ha⁻¹. Fresh baby corn samples were crushed using a pestle and mortar to measure total soluble solids (TSS) using a hand refractometer. Crude protein content was

determined by estimating total N content by the micro-Kjeldahl method (11), multiplying by 6.25 (12) and expressing it as a percentage. Ascorbic acid content was estimated by the volumetric method (13) and expressed as mg 100 g⁻¹ of sample.

Statistical analysis

The data collected throughout the investigation were analysed statistically using analysis of variance (ANOVA) suitable for FRBD in R software (version 4.6.0). Prior to ANOVA, the assumptions of normality and homogeneity of variances were assessed using the Shapiro-Wilk test and Levene's test, respectively. Both assumptions were satisfied ($p > 0.05$), confirming the suitability of the parametric ANOVA model. The significance of treatment effects (main effects of S and R and their interaction, S × R) was tested at the 5 % level of probability ($p = 0.05$) using the 'F' test (14). Whenever the 'F' test was significant, the treatment means were compared using the critical difference (CD) at a 5 % probability level. To compare the performance of each factorial treatment combination with the three control treatments, Dunnett's test was employed at a 5 % level of significance.

3. Results

Growth parameters

The data presented in Table 4 indicate that integrated nutrient management significantly influenced the growth parameters of baby corn. The nutrient ratio had a significant effect on plant height, with R₂ (25 : 75) having greater height than R₁. Nutrient source (S) and interaction had no significant effect, with mean values greater in S₂R₂. Comparing the treatments with the organic control using Dunnett's test (Supplementary Table 1) revealed that, except for T₁ and C₂, other treatments were significantly greater than C₁. Compared with C₂, only treatments T₆ (203.4 cm), T₈ (199.2 cm) and T₇ (197.2 cm) recorded significantly higher values, while T₁-T₅ and C₁ were statistically on par with C₂. All factorial treatments and the two nutrient-supplied controls (C₁ and C₂) recorded significantly greater plant height than the absolute control (C₃; 164.2 cm). Root length was significantly affected by the nutrient source, with vermicompost (S₂) recording the greatest length (52.5 cm), statistically on par with pig manure (S₃; 49.9 cm). Nutrient ratio and the source × ratio interaction had no significant effect, the numerically highest mean was recorded in S₂R₂ (25 % RDN through vermicompost: 55.5 cm). According to Dunnett's test (Supplementary Table 2), only T₆ was significantly higher than C₂ (44.6 cm) and C₃ (43.9 cm), while the remaining treatments were statistically on par with C₁, C₂ and C₃. A similar trend was observed with SPAD value, where only the nutrient source had a significant effect, with S₂ (vermicompost: 46.4) performing the best and S₄ (goat manure: 38.5) performing the least. Comparing the factorial and C₂ and C₃ treatments with the control C₁ (Supplementary Table 3), treatments T₆, T₂, T₇, T₅ and C₂ recorded significantly higher SPAD values. The inorganic control (C₂) recorded



a significantly higher SPAD value than both the organic control (C_1 : 35.5) and the absolute control (C_3 : 29.5), while C_1 and C_3 were statistically on par with each other. Dry matter of baby corn was significantly affected by nutrient source (S), nutrient ratio (R) and their interaction ($S \times R$). The nutrient source vermicompost (S_2 : 95 g plant⁻¹), ratio (25 : 75 : 83.5 g plant⁻¹) and interaction ($S_2 \times R_2$: 100.8 g plant⁻¹) recorded greater dry matter. Comparison with the control (Supplementary Table 4) showed that treatment T_1 (S_1R_1) was on par with C_1 and the treatment C_3 recorded significantly less dry matter than C_1 and all other treatments were significantly greater than C_1 . Treatment T_6 was significantly higher than C_2 and treatments T_7 , T_2 , T_4 and T_3 were on par with C_2 . All treatments were significantly higher compared to C_3 (41.3 g plant⁻¹).

Yield parameters

Cob yield was significantly influenced by nutrient source (Factor S) and nutrient ratio (Factor R), whereas their interaction ($S \times R$) was not significant (Table 5). The highest cob yield was recorded in S_2 (vermicompost: 12642.8 kg ha⁻¹) and R_2 (25 :75: 11232.1 kg ha⁻¹).

Dunnett's test showed (Supplementary Table 5) that T_6 , C_2 , T_5 and T_2 produced significantly higher cob yield than C_1 (100 % RDN through organic manure). Compared with C_2 (100 % RDN through inorganic fertiliser), none of the treatments was significantly superior, whereas T_6 , T_5 and T_2 were on par with C_2 . All treatments, including C_1 and C_2 , produced significantly higher cob yield than the absolute control (C_3). The percentage yield increase was highest with T_6 , C_2 , T_5 and T_2 , at 160 %, 145.8 %, 144.5 % and 137.4 %, respectively, over the absolute control. Fodder yield was significantly affected by source (S) and interaction, with S_2 (vermicompost: 28326 kg ha⁻¹) and S_3 (pig manure: 26165 kg ha⁻¹) on par with each other and S_2R_2 (25 % RDN through vermicompost: 31694 kg ha⁻¹) recorded the maximum. Dunnett's test revealed (Supplementary Table 6) that, except for treatments T_8 and C_3 , all other treatments were recorded significantly higher than C_1 . Treatment T_6 was significantly higher than C_2 and treatment C_1 and C_3 were significantly lower than C_2 and all factorial treatments recorded on par with C_2 . All factorial treatments and the inorganic control recorded significantly greater fodder yield than the absolute control (C_3 : 13423 kg ha⁻¹).

Table 4. Effect of integrated nutrient management on growth of baby corn

Factor S (nutrient source)	Plant height (cm)	Root length (cm)	SPAD	Dry matter (g plant ⁻¹)
S_1	190.6	47.4	40.9	68.5
S_2	196.3	52.5	46.4	95.0
S_3	193.7	49.9	42.2	85.5
S_4	194.3	46.5	38.5	74.0
SEd	2.8	1.9	1.6	3.0
CD ($p = 0.05$)	NS	4.1	3.4	6.6
Factor R (Nutrient ratio)				
R_1	188.8	48.2	40.9	78.0
R_2	198.6	50.0	43.2	83.5
SEd	2.0	1.3	1.1	2.1
CD ($p = 0.05$)	4.3	NS	NS	4.6
Interaction ($S \times R$)				
$S_1 \times R_1$	186.5	45.4	39.6	63.2
$S_2 \times R_1$	189.2	49.6	45.3	89.2
$S_3 \times R_1$	190.2	49.3	40.2	78.8
$S_4 \times R_1$	189.4	48.5	38.5	80.7
$S_1 \times R_2$	194.7	49.5	42.3	73.7
$S_2 \times R_2$	203.4	55.5	47.5	100.8
$S_3 \times R_2$	197.2	50.6	44.3	92.2
$S_4 \times R_2$	199.2	44.5	38.6	67.2
SEd	3.9	2.6	2.3	4.3
CD ($p = 0.05$)	NS	NS	NS	9.3
Control				
C_1	176.2	51.6	35.5	54.7
C_2	185.3	44.6	42.2	88.6
C_3	164.2	43.9	29.5	41.3

SEd: standard error of difference; CD: critical difference at 5 % significance level; NS: non-significant.



Table 5. Effect of integrated nutrient management on yield and quality of baby corn

Factor S (nutrient source)	Yield (kg ha ⁻¹)	Fodder yield (kg ha ⁻¹)	Crude protein (%)	Ascorbic acid (mg 100 g ⁻¹)	Total soluble solids (° Brix)
S ₁	10928.5	23013	11.2	32.8	5.9
S ₂	12642.8	28326	11.1	32.8	6.0
S ₃	9285.6	26165	10.3	25.5	5.4
S ₄	8535.6	21478	10.1	20.6	6.6
SEd	406.2	1466.4	0.4	1.2	0.2
CD (<i>p</i> = 0.05)	879.6	3145.2	0.9	2.6	0.5
Factor R (Nutrient ratio)					
R ₁	9464.2	24630	10.7	32.9	6.6
R ₂	11232.1	24860	10.7	22.8	5.3
SEd	287.2	1036.9	0.3	0.8	0.2
CD (<i>p</i> = 0.05)	622	NS	NS	1.8	0.4
Interaction (S × R)					
S ₁ × R ₁	9428.5	23777	10.9	40.3	6.5
S ₂ × R ₁	12071.3	24958	11.1	40.1	6.5
S ₃ × R ₁	8857.1	25622	10.5	30.6	6.0
S ₄ × R ₁	7499.9	24166	10.3	20.7	7.5
S ₁ × R ₂	12428.5	22250	11.5	25.2	5.3
S ₂ × R ₂	13214.2	31694	11.2	25.4	5.6
S ₃ × R ₂	9714.2	26708	10.2	20.3	4.8
S ₄ × R ₂	9571.4	18791	9.87	20.4	5.6
SEd	574.5	2073.8	0.6	1.7	0.3
CD (<i>p</i> = 0.05)	NS	4447.9	NS	3.6	NS
Control					
C ₁	8285.6	16889	9.74	20.2	6.6
C ₂	12499.9	23111	12.6	25.6	5.7
C ₃	5085.6	13423	9.25	21.3	5.6

SEd: standard error of difference; CD: critical difference at 5 % significance level; NS: non-significant.

Quality parameters

There was a significant difference in ascorbic acid because of different nutrient sources, ratios and their interaction. Among different manures, poultry manure and vermicompost were on par and the nutrient ratio of 50 : 50 performed better than 25 : 75. The combinations S₁R₁ and S₂R₁ recorded higher ascorbic acid content with values of 40.3 mg 100 g⁻¹ and 40.1 mg 100 g⁻¹, respectively. Comparing with C₁ (Supplementary Table 7), treatments T₁, T₂, T₃, T₅, T₆ and C₂ were significantly superior. Treatments T₅, T₆ and C₂ were on par with each other. When compared with the absolute control (C₃), only T₁, T₂ and T₃ recorded significantly different responses, whereas all other treatments, including C₁ and C₂, were statistically similar. Like ascorbic acid, TSS was significantly higher in 50 : 50 than 25 : 75. Among different manures, goat manure recorded the maximum value of 6.6 °Brix. The interaction effect was non-significant, with the mean value higher in S₄R₁ (7.5 °Brix). Only treatment T₄ was superior to C₁ and C₂

(Supplementary Table 8) and all other treatments were not significant. Similarly, poultry manure recorded significantly higher crude protein (11.2 %), which is on par with vermicompost (11.1 %) and the nutrient ratio and interaction had no significant effect. But by comparing it with the three controls (Supplementary Table 9), treatment C₂ (100 % RDN through inorganic fertiliser) recorded the maximum crude protein (12.63 %) and was on par with T₅, T₆ and T₂. The lowest was recorded in the absolute control (9.25 %).

4. Discussion

Integrated nutrient management is beneficial because it combines the strengths of both inorganic and organic sources. Inorganic fertilisers are readily available, so they supply nutrients quickly and meet the crop's demand during the early growth stages when rapid establishment is critical. Organic manures, on the other hand, release



nutrients slowly as they decompose, ensuring a steady and sustained supply throughout the crop's growth period. Integrating different organic manures (poultry, vermicompost, pig and goat manure) with inorganic fertiliser in 25 : 75 and 50 : 50 ratios had a significant effect on crop growth (plant height, root length, dry matter production), yield and quality of baby corn compared with the control. Among different manures, vermicompost produced maximum dry matter ($95.0 \text{ g plant}^{-1}$), root length (52.5 cm), chlorophyll content (46.4), baby corn yield ($12642.8 \text{ kg ha}^{-1}$), fodder yield (28326 kg ha^{-1}), crude protein (11.1%) and ascorbic acid ($32.8 \text{ mg } 100 \text{ g}^{-1}$). Despite containing lower phosphorus and potassium than pig manure, vermicompost outperformed it, a pattern likely explained by qualitative rather than purely quantitative differences in nutrient supply. This is because vermicompost is pre-digested by earthworms, enhancing microbial activity that speeds up nutrient mineralisation and renders nutrients more readily available to plants (15). Vermicompost is enriched with plant-available nutrients, N-fixing and phosphate-solubilising microorganisms and plant growth-promoting substances (16). It also typically has a lower C : N ratio than less stabilised manures, which could reduce N immobilisation during decomposition, although this interpretation was not directly measured here (17). Vermicompost also contains auxins, gibberellins and related bio stimulatory compounds that can enhance root and shoot growth independently of macronutrient supply alone (17). Greater plant height also contributed to better light interception and photosynthesis, which increased the dry matter and yield of baby corn. These findings are in line with the findings of previous researchers, where 75 % RDF + vermicompost at 2.5 t ha^{-1} + mixed biofertilisers performed better than FYM (18). The advantages of vermicompost over other manures have been reported in related crops. Previous reports compared the effect of FYM, goat manure and vermicompost (with a plant growth regulator) on the growth of baby corn and observed that vermicompost with 1-naphthaleneacetic acid (NAA) gave the best plant height, dry matter accumulation and green cob yield compared to all the organic manures tested and even the recommended-fertiliser control (19). Vermicompost application in radish resulted in greater plant height and dry weight compared with sole FYM and sole poultry manure applications when applied at the same level of N supply, suggesting a source-specific effect (20). Ascorbic acid was higher in poultry manure, this may be because poultry manure may contain high zinc and manganese content, which enhances ascorbic acid oxidase enzyme activity, the key determinant of ascorbic acid synthesis (21). This aligns with earlier reports, where the highest ascorbic acid was recorded in the treatment containing poultry manure + bio-fertiliser compared to vermicompost, pig manure and FYM (22).

The study shows that the combined application of organic and inorganic N sources, particularly a 25 : 75 ratio, outperformed both the 50 : 50 combination and the sole application of organic sources in growth (plant height and dry matter) and yield. This may be due to the

synchrony hypothesis, as baby corn has a narrow, sharply defined N-peak demand around the knee-high to tasselling stage, which is related to the rapid vegetative growth and early cob initiation (23). At 25 : 75, the larger inorganic fraction provided readily available N, enabling uptake to closely follow the crop demand (24). At 50 : 50, a greater share of N depended on microbial mineralisation of organic manure, a process governed by soil moisture, temperature and microbial activity rather than crop phenology (25). This created a temporal mismatch: the broader, delayed release curve of organic-N failed to align with the crop's narrow demand peak, so N became available either too early or too late, rather than being efficiently intercepted at peak demand (24). A similar pattern was observed in the case of baby corn by previous researchers, where 75 % N from urea and 25 % N from cow dung significantly improved plant height, chlorophyll content, dry matter and yield over the sole urea and 50 % urea + 50 % cow dung treatments (26). The same synchrony mechanism was found in radish by earlier researchers, who reported that the 75 % NPK plus 25 % N through vermicompost always produced better growth, yield and quality parameters than the 50 : 50 combination of NPK and N through vermicompost, suggesting that the yield advantage of higher inorganic-N ratios over balanced organic-inorganic mixes is not specific to one crop but is a common phenomenon (20).

Though the 25 : 75 combination of organic and inorganic N sources has increased growth and yield of baby corn, it does not contribute to quality. Among the two ratios, 50 % RDN had higher ascorbic acid and TSS. This apparent trade-off can be explained by the carbon-nitrogen balance (C/N) hypothesis of plant metabolism. The immediate availability of N (as in 25 : 75 and C_2) increases N assimilation and the use of carbon skeletons for amino acid biosynthesis, which facilitates protein synthesis (27). In contrast, under the slower organic-dominant release at 50 : 50, N availability is limiting relative to fixed carbon, shifting metabolism away from protein synthesis and toward carbon-based secondary metabolites such as ascorbic acid and TSS (28). The treatment C_2 , which is fully inorganic (100 % RDN through inorganic fertiliser) has higher crude protein (12.6 %) than other treatments. This is in line with the C/N-balance mechanism described above: continuous supply of inorganic N under C_2 ensured N assimilation into amino acids and proteins throughout the crop cycle, with no periodic N-limitation as observed under the organic-influenced treatments, thus maximising protein synthesis. Similar findings were reported, with the highest crude protein content observed in sweet corn under 100 % RDF through inorganic fertiliser (29). In terms of nutrient sources, the highest crude protein was found in S_1 (poultry manure: 11.2 %) and S_2 (vermicompost: 11.1 %), which is significantly higher than S_3 (pig manure: 10.3 %) and S_4 (goat manure: 10.1 %). This is probably due to the low C : N ratio and high N content of poultry manure, which allow for faster mineralisation and more N available for protein synthesis than the more slowly mineralising pig and goat manures (30). The performance of vermicompost is like that of the earthworm-mediated

mineralisation mechanism described above, which improves the availability of nutrients irrespective of the base substrate used.

The yield of combined application of organic and inorganic nitrogen sources was like the 100 % RDN through inorganic source, while it was significantly better than the organic and absolute control. Specifically, T₂, T₅ and T₆ produced yields on par with the inorganic control (C₂), indicating that up to 50 % of the recommended inorganic N dose can potentially be substituted with organic N without a statistically significant yield reduction. These findings align with previous studies (31, 32). A similar trend has been observed in recent studies reporting the same husk-inclusive yield metric. Sarker et al. reported that baby corn cob with husk yield was up to 13.86 t ha⁻¹ under 75 % RDN + cow dung, which is close to the best combination in the present study (13.21 t ha⁻¹). In earlier reports, 100 % RDN in enriched organic formulation was statistically comparable with potato-peel-compost formulation and sole FYM in baby corn cob yield, indicating that various combinations of organic and inorganic fertilisers can produce comparable results. The cob yield from 75 % RDF and poultry manure was statistically the same as 100 % RDF, which agrees with the present result that the cob yield from integrated nutrition was not inferior to that of 100 % RDF (32).

5. Conclusion

The present investigation demonstrated that the combined application of organic and inorganic nitrogen (N) sources significantly improved several growth and yield parameters of baby corn compared with sole organic N application. The results showed that no single ratio was best for all objectives; a higher proportion of inorganic-N was best for growth and yield, a better balance for quality parameters and sole inorganic fertilisation for crude protein, with vermicompost always being the best organic source. This suggests that the ratio of inorganic-N to organic-N should be adjusted according to the production goal, with a higher ratio of inorganic-N to organic-N for yield-oriented production and a more balanced ratio for quality-oriented production and/or reduced environmental risks. The study was carried out in one agroclimatic zone and there was no direct measurement of the soil N dynamics, future research is needed to confirm the proposed synchrony and test these combinations under different conditions and seasons and include economic analysis to support practical adoption.

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Authors' contributions

SG contributed to conceptualisation and writing original draft. KR contributed to supervision, investigation, review and editing. KP, JP and VAGV contributed to supervision. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest

Authors do not have any conflict of interests to declare.

Ethical issues

None

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During the preparation of this work the authors used Grammarly for grammar correction and language refinement. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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HePG

Supplementary Table 1. Effect of integrated nutrient management (INM) treatments on plant height as compared with 100 % recommended dose of nitrogen (RDN) through organic, 100 % RDN through inorganic and absolute control (Dunnett's test)

Treatment	Mean (cm)	vs T ₉ (100 % organic)		vs T ₁₀ (100 % inorganic)		vs T ₁₁ (Absolute control)	
		Estimate	Significance	Estimate	Significance	Estimate	Significance
T ₁	186.5	10.3	NS	1.2	NS	22.3	***
T ₂	189.2	13	*	3.9	NS	25	***
T ₃	190.2	14	*	4.9	NS	26	***
T ₄	189.4	13.2	*	4.1	NS	25.2	***
T ₅	194.7	18.5	***	9.4	NS	30.5	***
T ₆	203.4	27.2	***	18.1	**	39.2	***
T ₇	197.2	21	***	11.9	*	33	***
T ₈	199.2	23	***	13.9	*	35	***
C ₁	176.2	-	-	-9.1	NS	12	*
C ₂	185.3	9.1	NS	-	-	21.1	***
C ₃	164.2	-12	*	-21.1	***	-	-

Significance codes: *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; NS = not significant ($p > 0.10$).

Supplementary Table 2. Effect of integrated nutrient management treatments on root length as compared with 100 % recommended dose of nitrogen (RDN) through organic, 100 % RDN through inorganic and absolute controls (Dunnett's test)

Treatment	Mean (cm)	vs T ₉ (100 % organic)		vs T ₁₀ (100 % inorganic)		vs T ₁₁ (Absolute control)	
		Estimate	Significance	Estimate	Significance	Estimate	Significance
T ₁	45.4	-6.2	NS	0.80	NS	1.50	NS
T ₂	49.6	-2	NS	5.00	NS	5.70	NS
T ₃	49.3	-2.3	NS	4.70	NS	5.40	NS
T ₄	48.5	-3.1	NS	3.90	NS	4.60	NS
T ₅	49.5	-2.1	NS	4.90	NS	5.60	NS
T ₆	55.5	3.9	NS	10.90	**	11.60	**
T ₇	50.6	-1	NS	6.00	NS	6.70	NS
T ₈	44.5	-7.1	NS	-0.10	NS	0.60	NS
C ₁	51.6	-	-	-7.00	NS	7.70	NS
C ₂	44.6	7	NS	-	-	0.70	NS
C ₃	43.9	-7.7	NS	-0.70	NS	-	-

Significance codes: *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; NS = not significant ($p > 0.10$).

Supplementary Table 3. Effect of integrated nutrient management treatments on SPAD as compared with 100 % recommended dose of nitrogen (RDN) through organic, 100 % RDN through inorganic and absolute controls (Dunnett's test)

Treatment	Mean	vs T ₉ (100 % organic)		vs T ₁₀ (100 % inorganic)		vs T ₁₁ (Absolute control)	
		Estimate	Significance	Estimate	Significance	Estimate	Significance
T ₁	39.6	4.1	NS	-2.6	NS	10.1	**
T ₂	45.3	9.8	**	3.1	NS	15.8	***
T ₃	40.2	4.7	NS	-2	NS	10.7	***
T ₄	38.5	3	NS	-3.7	NS	9	**
T ₅	42.3	6.8	*	0.1	NS	12.8	***
T ₆	47.5	12	***	5.3	NS	18	***
T ₇	44.3	8.8	**	2.1	NS	14.8	***
T ₈	38.6	3.1	NS	-3.6	NS	9.1	**
C ₁	35.5	-	-	-6.7	*	6	NS
C ₂	42.2	6.7	*	-	-	12.7	***
C ₃	29.5	-6	NS	-12.7	***	-	-

Significance codes: *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; NS = not significant ($p > 0.10$).

Supplementary Table 4. Effect of integrated nutrient management treatments on dry matter as compared with 100 % recommended dose of nitrogen (RDN) through organic, 100 % RDN through inorganic and absolute controls (Dunnett's test)

Treatment	Mean (g plant ⁻¹)	vs T ₉ (100 % organic)		vs T ₁₀ (100 % inorganic)		vs T ₁₁ (Absolute control)	
		Estimate	Significance	Estimate	Significance	Estimate	Significance
T ₁	63.2	8.5	NS	-25.37	***	21.97	***
T ₂	89.2	34.47	***	0.6	NS	47.93	***
T ₃	78.8	24.1	***	-9.77	NS	37.57	***
T ₄	80.7	25.97	***	-7.9	NS	39.43	***
T ₅	73.7	19	**	-14.87	*	32.47	***
T ₆	100.8	46.07	***	12.2	*	59.53	***
T ₇	92.2	37.43	***	3.57	NS	50.9	***
T ₈	67.2	12.47	*	-21.4	***	25.93	***
C ₁	54.7	-	-	-33.87	***	13.47	*
C ₂	88.6	33.87	***	-	-	47.33	***
C ₃	41.3	-13.47	*	-47.33	***	-	-

Significance codes: *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; NS = not significant ($p > 0.10$).

Supplementary Table 5. Effect of integrated nutrient management treatments on cob yield as compared with 100 % recommended dose of nitrogen (RDN) through organic, 100 % RDN through inorganic and absolute controls (Dunnett's test)

Treatment	Mean (kg ha ⁻¹)	vs T ₉ (100 % organic)		vs T ₁₀ (100 % inorganic)		vs T ₁₁ (Absolute control)	
		Estimate	Significance	Estimate	Significance	Estimate	Significance
T ₁	9428.5	1142.8	NS	-3071.4	***	4342.8	***
T ₂	12071.3	3785.7	***	-428.6	NS	6985.7	***
T ₃	8857.1	571.4	NS	-3642.8	***	3771.4	***
T ₄	7499.9	-785.7	NS	-5000	***	2414.3	**
T ₅	12428.5	4142.8	***	-71.4	NS	7342.8	***
T ₆	13214.2	4928.5	***	714.3	NS	8128.5	***
T ₇	9714.2	1428.6	NS	-2785.7	***	4628.5	***
T ₈	9571.4	1285.7	NS	-2928.6	***	4485.7	***
C ₁	8285.65	-	-	-4214.2	***	3200	***
C ₂	12499.9	4214.2	***	-	-	7414.2	***
C ₃	5085.6	-3200	***	-7414.2	***	-	-

Significance codes: *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; NS = not significant ($p > 0.10$).

Supplementary Table 6. Effect of integrated nutrient management treatments on fodder yield as compared with 100 % recommended dose of nitrogen (RDN) through organic, 100 % RDN through inorganic and absolute controls (Dunnett's test)

Treatment	Mean (kg ha ⁻¹)	vs T ₉ (100 % organic)		vs T ₁₀ (100 % inorganic)		vs T ₁₁ (Absolute control)	
		Estimate	Significance	Estimate	Significance	Estimate	Significance
T ₁	23777	6888	*	666	NS	10354	***
T ₂	24958	8069	**	1847	NS	11535	***
T ₃	25622	8734	**	2512	NS	12200	***
T ₄	24166	7277	**	1055	NS	10743	***
T ₅	22250	5361	*	-861	NS	8827	**
T ₆	31694	14805	***	8583	**	18271	***
T ₇	26708	9820	***	3597	NS	13286	***
T ₈	18791	1903	NS	-4319	NS	5369	*
C ₁	16889	-	-	-6222	*	3466	NS
C ₂	23111	6222	*	-	-	9688	***
C ₃	13423	-3466	NS	-9688	***	-	-

Significance codes: *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; NS = not significant ($p > 0.10$).

Supplementary Table 7. Effect of integrated nutrient management treatments on ascorbic acid as compared with 100 % recommended dose of nitrogen (RDN) through organic, 100 % RDN through inorganic and absolute controls (Dunnett's test)

Treatment	Mean (mg 100 g ⁻¹)	vs T ₉ (100 % organic)		vs T ₁₀ (100 % inorganic)		vs T ₁₁ (Absolute control)	
		Estimate	Significance	Estimate	Significance	Estimate	Significance
T ₁	40.3	20.1	***	14.7	***	19	***
T ₂	40.1	19.9	***	14.5	***	18.8	***
T ₃	30.6	10.4	***	5	*	9.3	***
T ₄	20.7	0.5	NS	-4.9	*	-0.6	NS
T ₅	25.2	5	*	-0.4	NS	3.9	NS
T ₆	25.4	5.2	*	-0.2	NS	4.1	NS
T ₇	20.3	0.1	NS	-5.3	*	-1	NS
T ₈	20.4	0.2	NS	-5.2	*	-0.9	NS
C ₁	20.2	-	-	-5.4	*	-1.1	NS
C ₂	25.6	5.4	*	-	-	4.3	NS
C ₃	21.3	1.1	NS	-4.3	NS	-	-

Significance codes: *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; NS = not significant ($p > 0.10$).

Supplementary Table 8. Effect of integrated nutrient management treatments on total soluble solids (TSS) as compared with 100 % through recommended dose of nitrogen (RDN) organic, 100 % through RDN inorganic and absolute controls (Dunnett's test)

Treatment	Mean (°Brix)	vs T ₉ (100 % organic)		vs T ₁₀ (100 % inorganic)		vs T ₁₁ (Absolute control)	
		Estimate	Significance	Estimate	Significance	Estimate	Significance
T ₁	6.53	-0.03	NS	0.83	NS	0.93	NS
T ₂	6.50	-0.07	NS	0.80	NS	0.90	NS
T ₃	5.97	-0.60	NS	0.27	NS	0.37	NS
T ₄	7.53	0.97	*	1.83	***	1.93	***
T ₅	5.30	-1.27	**	-0.40	NS	-0.30	NS
T ₆	5.57	-1.00	*	-0.13	NS	-0.03	NS
T ₇	4.83	-1.73	***	-0.87	NS	-0.77	NS
T ₈	5.57	-1.00	*	-0.13	NS	-0.03	NS
C ₁	6.57	-	-	-0.87	NS	0.97	*
C ₂	5.70	0.87	NS	-	-	0.10	NS
C ₃	5.60	-0.97	*	-0.10	NS	-	-

Significance codes: *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; NS = not significant ($p > 0.10$).

Supplementary Table 9. Effect of integrated nutrient management treatments on crude protein as compared with 100 % recommended dose of nitrogen (RDN) through organic, 100 % RDN through inorganic and absolute controls (Dunnett's test)

Treatment	Mean (%)	vs T ₉ (100 % organic)		vs T ₁₀ (100 % inorganic)		vs T ₁₁ (Absolute control)	
		Estimate	Significance	Estimate	Significance	Estimate	Significance
T ₁	10.9	1.15	NS	-1.74	*	1.64	NS
T ₂	11.1	1.31	NS	-1.58	NS	1.8	*
T ₃	10.5	0.8	NS	-2.09	*	1.29	NS
T ₄	10.3	0.54	NS	-2.35	**	1.03	NS
T ₅	11.5	1.77	*	-1.12	NS	2.26	**
T ₆	11.2	1.5033	NS	-1.3867	NS	1.9933	*
T ₇	10.2	0.41	NS	-2.48	**	0.9	NS
T ₈	9.87	0.13	NS	-2.76	***	0.62	NS
C ₁	9.74	-	-	-2.89	***	0.49	NS
C ₂	12.6	2.89	***	-	-	3.38	***
C ₃	9.25	-0.49	NS	-3.38	***	-	-

Significance codes: *** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; NS = not significant ($p > 0.10$).