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# Forage Nutritive Quality, Yield and Quantitative Analysis of Leguminous Fodder Cowpea-Maize System as Influenced by Integrated Nutrient Management in Southern Zone of India

S.R. Shri Rangasami[1], S. Rani[2], S.D. Sivakumar[3], K.N. Ganesan[4]

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## ABSTRACT

**Background:** A significant impediment to the advancement of animal husbandry in India is the insufficient availability of green fodder throughout the year. The nutritive quality of forages is heavily influenced by farm-level management practices. Consequently, there is a pressing need to enhance productivity through the implementation of proper agronomic practices. The nutrient management in fodder-based cropping sequence is a key to maximize the fodder production and its quality.

**Methods:** A field experiment was conducted using a randomized block design, consisting of twelve treatments incorporating various organic sources of nutrients. The experiment was replicated thrice during *Kharif* and *Rabi* season 2020-22 at Department of Forage Crops, Tamil Nadu Agricultural University, Coimbatore. The treatments included different proportions (100, 75, 50 and 25%) of the recommended dose of nitrogen applied through FYM, vermicompost and bio compost.

**Result:** The experiment results of the three years study revealed that application of 50% RDN through FYM+ 50% RDN through vermicompost recorded the higher green fodder yield of 691 q/ha, dry matter yield of 130.7 q/ha and crude protein yield of 19.3 q/ha. Correlation and regression analysis also indicated that the growth and yield attributes had a positive impact on the fodder yield. Hence it can be recommended that application of FYM and vermicompost (50 and 50% RDN) found better source of organic nutrients for achieving sustainable and economical fodder yield with quality in fodder cowpea-maize cropping system.

**Key words:** Economics, Fodder cowpea, Fodder maize, Nutritive quality, Organic nutrients, Yield.

## INTRODUCTION

Livestock, serving as an integral component of agriculture, holds a crucial role in sustaining and enhancing agricultural productivity across diverse farming systems. Fodder, a vital element in profitable animal production in India, faces a precarious supply situation with a significant gap (Kumar *et al*., 2021; Rajpoot *et al*., 2021). Despite the pivotal role played by inorganic fertilizers in meeting crop nutrient requirements for normal growth and development, their usage poses threats to sustainability and environmentally friendly agricultural practices due to nutrient depletion and leaching (Kumar and Choudhary, 2023). Consequently, there is a pressing need to reduce the reliance on chemical fertilizers and, in turn, increase the utilization of locally available farm waste for the preparation of organic manures, such as FYM, vermicompost and bio compost (Gupta *et al*., 2022). These organic sources offer a cost-effective means for sustainable agricultural production.

However, from an economic perspective, it is impractical to exclusively fulfill crop nutrient requirements through organic manures or biological sources due to their substantial demand in terms of quantity, limited nutrient supply potential and various alternative uses, particularly in developing countries (Shrivas *et al*., 2023). Integrated nutrient management (INM) emerges as a concept that integrates traditional and modern nutrient management methods into an ecologically sound and economically optimal farming system. The objective is to ensure food security and enhance environmental quality by minimizing nutrient losses (Harish *et al*. 2022a, 2022b). In consideration of these factors, this study was conducted with the aim of investigating the impact of organic sources of nutrients on the forage yield and quality of the fodder cowpea and maize cropping system.

[1]Department of Forage Crops, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.
[2]Department of Agronomy, Agricultural College and Research Institute, Madurai-625 104, Tamil Nadu, India.
[3]Department of Agronomy, Institute of Agriculture, Kumulur-521 712, Tamil Nadu, India.
[4]Department of Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.

**Corresponding Author:** S.R. Shri Rangasami, Department of Forage Crops, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India. Email: shrirangasamisr@tnau.ac.in

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## MATERIALS AND METHODS

A field experiment was conducted during *Kharif* and *Rabi* seasons of 2020 to 2022 at the Department of Forage Crops, Tamil Nadu Agricultural University, Coimbatore. The primary objective was to investigate the effect of organic sources of nutrients on the fodder cowpea and maize cropping system. The experiment utilized a randomized block design with three replications and 12 treatments as follows: $T_1$-100% recommended dose of nitrogen (RDN) through inorganic fertilizers, $T_2$-100% RDN through FYM, $T_3$-75% RDN through FYM + 25% RDN through vermicompost (VC), $T_4$-75% RDN through FYM+ 25% RDN through bio-compost. (BC) $T_5$-50% RDN through FYM+ 50% RDN through VC, $T_6$-50% RDN through FYM+ 50% RDN through BC, $T_7$-75% RDN through FYM, $T_8$-75% RDN of $T_3$ (56% RDN through FYM+ 19% RDN through VC), $T_9$-75% RDN of $T_4$ (56% RDN through FYM+ 19% RDN through BC), $T_{10}$-75% of $T_5$ (37.5% RDN through FYM+ 37.5% RDN through VC), $T_{11}$-75% of $T_6$ (37.5% RDN through FYM+ 37.5% RDN through VC) and $T_{12}$-50% RDN through FYM+ 25% RDN through VC + 25% RDN through BC at 30 days after sowing (DAS).

The experimental field featured clay loam soil with an organic carbon content of 0.37%. The soil had an electrical conductivity (EC) of 0.41 dSm$^{-1}$ and pH 7.6. Nitrogen availability in the soil was low at 268.8 kg ha$^{-1}$, phosphorus availability was medium at 11.6 kg ha$^{-1}$ and potassium availability was high at 507 kg ha$^{-1}$. For the first crop of fodder cowpea (CO-9), sowing took place in the first fortnight of July, with a recommended spacing of 30 cm between rows. The recommended doses of phosphorus (P) and potassium (K) were 60 kg ha$^{-1}$ and 0 kg ha$^{-1}$, respectively, applied at the time of sowing. Harvesting occurred at 50% flowering, approximately 55-60 days after sowing (DAS).

The second crop of fodder maize (African Tall) was sown in the first fortnight of October, with the same recommended spacing. Phosphorus and potassium were applied at recommended rates of 60 kg ha$^{-1}$ and 40 kg ha$^{-1}$, respectively, at the time of sowing. Harvesting occurred at the dough stage, approximately 70-75 DAS. Cultural practices followed the recommended package for crop establishment.

A total of 110 kg N/ha, recommended for the cropping system, was applied in two equal splits. Fifty percent of the recommended dose of nitrogen (RDN) for fodder cowpea (55 N kg ha$^{-1}$) and the remaining 50% RDN (55 N kg ha$^{-1}$) were applied to fodder maize using different sources of organic manures based on N equivalent three weeks prior to sowing. Available phosphorus and potassium were provided and no inorganic fertilizers were used to meet phosphorous and potassium equivalents. Green fodder yield was recorded immediately after crop harvest, with samples taken and oven-dried at 70°C for dry matter content and other quality parameter estimations. Economic analysis considered prevailing market prices for output and input costs. Data on various parameters were statistically analyzed using Fisher's ANOVA method, as recommended by Gomez and Gomez (2010).

### Quantitative variables analysis

The research methodology utilized a two-pronged strategy, involving both correlation analysis and multiple linear regressions, to investigate the intricate relationships between various plant characteristics and the green fodder yield of cowpea and maize. Correlation analysis, a crucial statistical technique, was employed to assess the degree of association among different variables (Ravi *et al*., 2023). Specifically, the Pearson correlation coefficient (PCC) was used to precisely gauge the strength and direction of these relationships (Ajaykumar *et al*., 2022). Widely acknowledged, the PCC establishes a vital link between anticipated and observed values, thereby enhancing our understanding of their alignment (Benesty *et al*., 2009).

The variables under examination in this study include green forage yield (q/ha), plant height (cm), leaf stem ratio, crude fiber (%), ether extract (%), ash (%), carbohydrates (%), crude protein content (%), crude protein yield (q/ha) and dry matter yield (q/ha) (Ajaykumar *et al*., 2023). Correlation analysis was employed to unveil the associations among these variables, offering insights into their impact on green forage yield. This analytical process was executed using the relevant mathematical formula, enabling precise quantification of these interrelationships.

Through the comprehensive application of this approach, our goal was to gain a deeper understanding of the factors influencing green forage yield. This objective can be expressed mathematically as follows:

$$r_{xy} = \frac{S_{xy}}{S_x S_y} = \frac{\Sigma\,(x_i - \bar{x})\,(y_i - \bar{y})}{\sqrt{[\Sigma\,(x_i - \bar{x})^2]\,[\Sigma\,(y_i - \bar{y})^2]}}$$

In this context, the coefficient '$r_{xy}$' indicates the extent of the linear relationship between the variables x and y, where '$S_x$' and '$S_y$' denote the sample standard deviations. The term '$S_{xy}$' represents the sample covariance, with '$x_i$' and '$y_i$' representing the respective values of the x and y variables within the sample derived from the population. Additionally, x and y signify the sample means. Another valuable econometric method employed in this study is regression analysis, which thoroughly examines the relationship between a dependent variable and a set of independent variables. This methodology is supported by previous research conducted by Maulud and Abdulazeez *et al*. (2020) and is expressed as follows:

$$Y_i = \alpha + \beta X_i + \mu_i$$

In this particular context, '$y_i$' represents the dependent variable, specifically associated with green forage yield, while '$x_i$' denotes a set of independent variables, including plant height (cm), leaf stem ratio, crude fibre (%), ether extract (%), ash (%), carbohydrates (%), crude protein content (%) and crude protein yield (q/ha). In this framework, the coefficient 'β' plays the role of representing the slope coefficient corresponding to each independent variable, 'á' serves as the constant or intercept term and '$u_i$' encompasses the error term. The structured equation for this regression model can be elegantly reformulated as follows:

$$\text{Green forage yield (q ha}^{-1}) = \alpha + \beta_1 \text{ plant height (cm)} + \beta_2 \text{ leaf stem ratio} + \beta_3 \text{ crude fibre (\%)} + \beta_4 \text{ Ether extract (\%)} + \beta_5 \text{ Ash (\%)} + \beta_6 \text{ Carbohydrates (\%)} + \beta_7 \text{ Crude protein content (\%)} + \beta_8 \text{ Crude protein yield (q/ha)} + \mu_i$$

## RESULTS AND DISCUSSION

### Plant height and leaf stem ratio

The plant height and leaf stem ratio of fodder cowpea and maize as influenced by organic source of nutrients recorded at harvest as presented in Table 1.

The application of 100% recommended dose of fertilizers (RDF) through inorganic fertilizers resulted in significantly higher plant height (104.4 cm for fodder cowpea and 231.7 cm for maize) and leaf-to-stem ratio (0.66 for fodder cowpea and 0.45 for maize). Conversely, the effect of organic sources of nutrients on forage quality in both fodder cowpea and maize was found to be non-significant.

However, the application of 50% recommended dose of nitrogen (RDN) through farmyard manure (FYM) + 50% RDN through vermicompost (VC) led to a significantly higher plant height (98.1 cm for fodder cowpea and 226.2 cm for maize). This can be attributed to the early availability of nutrients from inorganic sources during the initial stages, coupled with an increased nutrient supply from integrated sources in the later stages, owing to efficient nutrient utilization and gradual nutrient release. The elevated mineralization potential and continuous nutrient release by FYM and VC likely exerted a positive influence on growth characteristics. The higher nutrient content and rapid nitrogen release from organic manure may explain the observed higher plant height and leaf-to-stem ratio (Gupta *et al*., 2022; Bhupenchandra *et al*., 2024).

### Quality characters

The utilization of organic nutrient sources significantly influenced both crude protein yield and content in the fodder cowpea-maize cropping system, with detailed data presented in Table 2 and 3. Notably, the application of 50% RDN through FYM + 50% RDN through VC resulted in a significantly higher crude protein yield (19.3 q ha$^{-1}$). Following closely was the treatment of 75% RDN through FYM + 25% RDN through VC, which recorded a crude protein yield of 18.06 q ha$^{-1}$. In contrast, a lower crude protein yield (14.6 q ha$^{-1}$) was observed with the application of 75% RDN through FYM. This outcome can be attributed to the increased dry matter yield and higher crude protein content associated with a higher N dose (Harish *et al*., 2022a; Varatharajan *et al*., 2022). The assumption is that the treatment with greater nutrient content, including bio-compost and other organic nutrients, led to higher nutrient translocation within the plant system (Dabhi *et al*., 2017; Patel *et al*., 2018).

On the other hand, the application of 100% RDF through inorganic fertilizers significantly increased the content of fiber (28 and 27.6%), Ether extract (3.0 and 3.1%), Ash (10.4 and 8.9%) and carbohydrates (30.2 and 31.6%) in fodder cowpea and maize, respectively. Organic sources of nutrients, however, did not exert a significant influence on the quality of forage in both fodder cowpea and maize.

Nevertheless, the application of 50% RDN through FYM+ 25% RDN through VC + 25% RDN through bio-compost (BC) at 30 days after sowing (DAS) recorded numerically higher crude fiber (29.8% for fodder cowpea and 29.5% for maize), ether extract (2.7% for fodder cowpea and 2.9% for maize), ash (8.9% for fodder cowpea and 8.1% for maize) and carbohydrates (28.7% for fodder cowpea and 29.6% for maize). The significant decrease in crude fiber

**Table 1:** Effect of organic source of nutrients on growth attributers of fodder cowpea and maize in fodder cropping system (Pooled data).

| Treatments | Plant height (cm) | | Leaf stem ratio | |
|---|---|---|---|---|
| | Cowpea | Maize | Cowpea | Maize |
| $T_1$ | 104.4 | 231.7 | 0.66 | 0.45 |
| $T_2$ | 89.2 | 223.4 | 0.57 | 0.35 |
| $T_3$ | 95.7 | 207.8 | 0.50 | 0.29 |
| $T_4$ | 90.9 | 210.8 | 0.48 | 0.32 |
| $T_5$ | 98.1 | 226.2 | 0.51 | 0.35 |
| $T_6$ | 94.0 | 209.8 | 0.54 | 0.34 |
| $T_7$ | 78.6 | 188.2 | 0.53 | 0.29 |
| $T_8$ | 85.1 | 193.7 | 0.48 | 0.27 |
| $T_9$ | 78.0 | 206.0 | 0.47 | 0.28 |
| $T_{10}$ | 84.0 | 196.6 | 0.45 | 0.26 |
| $T_{11}$ | 78.3 | 190.0 | 0.44 | 0.25 |
| $T_{12}$ | 91.9 | 211.4 | 0.59 | 0.37 |
| S.Em± | 3.16 | 7.43 | 0.12 | 0.11 |
| CD @ 5% | 9.41 | 22.1 | 0.34 | 0.33 |

content with increased N content in herbage is attributed to the transformation of synthesized carbohydrates into proteins (Harish *et al*., 2022a). Plants rich in N content exhibit a higher proportion of water, lower dry matter content, more succulent leaves and lower crude fiber content. Elevated nitrogen content enhances meristematic activity, leading to increased absorption of mineral salts, rapid respiration, conversion of most carbohydrates into fat and active participation in protein synthesis. Nitrogen-free extract, a component of carbohydrates, is also influenced by nitrogen.

**Green forage yield**

The green forage yield of fodder cowpea and maize as influenced by organic source of nutrients recorded at harvest is presented in Table 4. The green forage yield of fodder cowpea exhibited a significant impact based on the organic nutrient source. Among these sources, the highest green forage yield was observed with the application of 50% RDN through FYM+ 50% RDN through BC, reaching 263 q ha$^{-1}$. Conversely, the lowest green forage yield was recorded with 75% RDN through FYM, amounting to 185 q ha$^{-1}$.

In the case of fodder maize, a significantly higher green forage yield was noted with the application of 50% RDN through FYM + 50% RDN through VC, reaching 428 q ha$^{-1}$. This result was comparable to the yield obtained with 75% RDN through FYM + 25% RDN through VC, which reached 421 q ha$^{-1}$. Conversely, the application of 75% RDN through FYMresulted in a lower green forage yield of 367 q ha$^{-1}$. The increase in green forage yield can be attributed to the

**Table 2:** Effect of organic source of nutrients on quality of fodder cowpea-maize system (Pooled data).

| Treatments | Fodder cowpea | | | | Fodder maize | | | |
|---|---|---|---|---|---|---|---|---|
| | Crude fibre (%) | Ether extract (%) | Ash (%) | Carbohydrates (%) | Crude fibre (%) | Ether extract (%) | Ash (%) | Carbohydrates (%) |
| $T_1$ | 28.0 | 3.0 | 10.4 | 30.2 | 27.6 | 3.1 | 8.9 | 31.6 |
| $T_2$ | 28.8 | 2.5 | 9.1 | 27.9 | 29.1 | 2.6 | 7.7 | 28.9 |
| $T_3$ | 28.9 | 2.2 | 8.2 | 26.7 | 27.2 | 2.5 | 7.4 | 28.3 |
| $T_4$ | 27.4 | 2.1 | 8.6 | 27.1 | 27.6 | 2.4 | 7.5 | 27.9 |
| $T_5$ | 28.0 | 2.4 | 8.3 | 26.7 | 28.4 | 2.6 | 7.4 | 26.9 |
| $T_6$ | 27.3 | 2.4 | 8.3 | 27.6 | 27.8 | 2.7 | 8.0 | 26.4 |
| $T_7$ | 26.9 | 2.2 | 8.1 | 27.7 | 28.0 | 2.5 | 6.9 | 28.9 |
| $T_8$ | 25.8 | 2.0 | 7.4 | 26.6 | 27.0 | 2.6 | 7.1 | 25.2 |
| $T_9$ | 26.2 | 2.1 | 7.3 | 26.5 | 26.9 | 2.4 | 6.5 | 26.2 |
| $T_{10}$ | 25.8 | 2.1 | 7.5 | 26.1 | 27.1 | 2.5 | 6.8 | 26.0 |
| $T_{11}$ | 25.9 | 2.0 | 7.5 | 26.3 | 26.2 | 2.4 | 6.7 | 26.3 |
| $T_{12}$ | 29.8 | 2.7 | 8.9 | 28.7 | 29.5 | 2.9 | 8.1 | 29.6 |
| S.Em± | 1.38 | 0.22 | 1.61 | 0.84 | 1.01 | 0.11 | 0.61 | 1.51 |
| CD @ 5% | 3.99 | 0.68 | 4.79 | 2.58 | 2.85 | 0.32 | 2.02 | 4.38 |

**Table 3:** Crude protein content (%) and Crude protein yield (q/ha) of fodder cowpea and maize as influenced by organic source of nutrients (Pooled data).

| Treatments | Crude protein content (%) | | Crude protein yield (q/ha) | | |
|---|---|---|---|---|---|
| | Cowpea | Maize | Cowpea | Maize | System |
| $T_1$ | 18.0 | 13.0 | 9.57 | 12.40 | 21.97 |
| $T_2$ | 18.2 | 12.9 | 6.63 | 10.10 | 16.73 |
| $T_3$ | 18.4 | 12.8 | 7.83 | 10.23 | 18.06 |
| $T_4$ | 18.2 | 9.2 | 6.77 | 9.43 | 16.20 |
| $T_5$ | 18.4 | 10.1 | 8.50 | 10.83 | 19.33 |
| $T_6$ | 18.4 | 9.7 | 7.17 | 9.57 | 16.74 |
| $T_7$ | 18.2 | 9.2 | 6.07 | 8.50 | 14.57 |
| $T_8$ | 18.5 | 9.4 | 6.57 | 9.00 | 15.57 |
| $T_9$ | 18.2 | 8.7 | 6.00 | 8.83 | 14.83 |
| $T_{10}$ | 18.4 | 9.5 | 6.93 | 9.40 | 16.33 |
| $T_{11}$ | 18.4 | 8.8 | 6.43 | 9.37 | 15.80 |
| $T_{12}$ | 18.5 | 9.5 | 7.23 | 9.83 | 17.06 |
| S.Em± | 0.32 | 0.43 | 0.27 | 0.37 | 0.47 |
| CD @ 5% | 0.82 | 1.18 | 0.83 | 1.08 | 1.38 |

taller plant height, higher leaf-to-stem ratio and rapid nutrient release from BC, contributing to improved plant growth and greater green biomass (Rajpoot *et al*., 2021; Bhupenchandra *et al*., 2022, 2024). Among the organic sources of nutrients, the application of 50% RDN through FYM + 50% RDN through vermicompost recorded higher system productivity at 691 q ha$^{-1}$. This was comparable to the system productivity achieved with 75% RDN through FYM+ 25% RDN through vermicompost, amounting to 666 q ha$^{-1}$. In contrast, lower system productivity was observed with the application of 75% RDN through FYM, reaching 552 q ha$^{-1}$.

### Dry matter yield

The dry matter production of fodder cowpea and maize was significantly affected by the application of organic nutrients and the relevant data is presented in Table 4. For fodder cowpea, the application of 50% RDN through FYM+ 50% RDN through vermicompost resulted in a significantly higher dry matter yield (46.3 q ha$^{-1}$), comparable to the yield achieved with 75% RDN through FYM+ 25% RDN through vermicompost (42.5 q ha$^{-1}$). In the case of fodder maize, the application of 50% RDN through FYM+ 50% RDN through vermicompost also led to a significantly higher dry matter yield (84.4 q ha$^{-1}$), equivalent to the yield obtained with 75% RDN through FYM+ 25% RDN through vermicompost (79.8 q ha$^{-1}$). Conversely, a lower dry matter yield was observed with 75% RDN through FYM (66.1 q ha$^{-1}$).

Among the organic sources, the application of 50% RDN through FYM+ 50% RDN through vermicompost resulted in a significantly higher system dry matter yield (130.7 q ha$^{-1}$), matching the yield achieved with 75% RDN through FYM+ 25% RDN through vermicompost (122.3 q ha$^{-1}$). The increase in dry matter yield is primarily attributed to the rise in green biomass and dry matter content. Additionally, improved partitioning and photosynthetic rates, evidenced by enhanced nutrient uptake, facilitated robust plant growth, leading to increased interception, absorption and utilization of solar radiation. This, in turn, resulted in a higher photosynthetic rate and improved partitioning, ultimately leading to increased accumulation and production of dry matter (Suri and Choudhary, 2012).

### Quantitative analysis

**Table 4:** Effect of organic source of nutrients on yield of fodder cowpea-maize system (Pooled data).

| Treatments | Green forage yield (q/ha) | | | Dry matter yield (q/ha) | | |
|---|---|---|---|---|---|---|
| | Cowpea | Maize | System | Cowpea | Maize | System |
| $T_1$ | 282 | 459 | 741 | 53.1 | 95.6 | 148.7 |
| $T_2$ | 200 | 415 | 615 | 36.5 | 78.4 | 114.9 |
| $T_3$ | 245 | 421 | 666 | 42.5 | 79.8 | 122.3 |
| $T_4$ | 205 | 393 | 598 | 37.1 | 73.5 | 110.6 |
| $T_5$ | 263 | 428 | 691 | 46.3 | 84.4 | 130.7 |
| $T_6$ | 220 | 405 | 625 | 39.0 | 74.2 | 113.3 |
| $T_7$ | 185 | 367 | 552 | 33.3 | 66.1 | 99.4 |
| $T_8$ | 198 | 383 | 581 | 35.6 | 69.8 | 105.4 |
| $T_9$ | 178 | 381 | 559 | 32.9 | 68.9 | 101.7 |
| $T_{10}$ | 215 | 399 | 614 | 37.6 | 73.1 | 110.7 |
| $T_{11}$ | 195 | 404 | 599 | 34.9 | 72.8 | 107.8 |
| $T_{12}$ | 225 | 408 | 633 | 39.1 | 76.3 | 115.5 |
| S.Em± | 8.12 | 11.73 | 20.11 | 1.51 | 2.34 | 3.39 |
| CD @ 5% | 24.27 | 34.63 | 59.42 | 4.37 | 6.52 | 11.16 |

**Table 5:** Descriptive statistics of the plant characteristics and yield attributes of fodder cowpea-maize system.

| Statistic | Green forage yield (q/ha) | Plant height (cm) | Leaf stem ratio | Crude fibre (%) | Ether extract (%) | Ash (%) | Carbohydrates (%) | Crude protein content (%) | Crude protein yield (q/ha) | Dry matter yield (q/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| Minimum | 178.00 | 78.00 | 0.25 | 25.80 | 2.00 | 6.50 | 25.20 | 8.70 | 6.00 | 32.90 |
| Maximum | 459.00 | 231.70 | 0.66 | 29.80 | 3.10 | 10.40 | 31.60 | 18.50 | 12.40 | 95.60 |
| 1st Quartile | 212.50 | 90.48 | 0.31 | 26.90 | 2.20 | 7.38 | 26.38 | 9.50 | 6.89 | 37.48 |
| Median | 324.50 | 146.30 | 0.45 | 27.50 | 2.45 | 7.60 | 27.00 | 15.50 | 8.67 | 59.60 |
| 3rd Quartile | 404.25 | 208.30 | 0.50 | 28.10 | 2.60 | 8.30 | 28.40 | 18.40 | 9.57 | 73.68 |
| Mean | 311.42 | 148.49 | 0.42 | 27.55 | 2.45 | 7.86 | 27.51 | 14.28 | 8.47 | 57.53 |
| Variance | 9949.04 | 3821.20 | 0.01 | 1.31 | 0.09 | 0.81 | 2.34 | 18.36 | 2.87 | 405.01 |
| Standard deviation | 99.74 | 61.82 | 0.12 | 1.14 | 0.30 | 0.90 | 1.53 | 4.28 | 1.69 | 20.12 |

The descriptive statistics of growth and yield attributes are represented in Table 5. The correlation results (Table 6) showed that all the variables included in the model were positively significant at 1% level of significance and these signs emphasize all the variables would attribute to the green forage yield of cowpea and maize. The correlation coefficients between green forage yield and various factors, such as plant height (0.98), ether extraction (0.64), crude protein yield (0.93) and dry matter yield (0.99), underscore robust positive relationships among these attributes (Fig 1). In contrast, attributes like leaf stem ratio (-0.74) and crude protein content (-0.89) exerted negative influences on forage yield. Consequently, all these variables were incorporated as independent factors in the subsequent multiple linear regression model.

The goal of the multiple linear regressions was to quantitatively evaluate the relationships and clarify the extent of influence each specified parameter has on green forage yield (Ajaykumar *et al*., 2023). The resulting multiple linear regression equation is as follows:

Green forage yield (q ha$^{-1}$) =
-4.06 + 0.37 plant height (cm) - 240.84 leaf stem ratio + 2.51 crude fiber (%) + 28.70 ether extract (%) + 1.09 ash (%) + 0.41 carbohydrates (%) - 1.86 crude protien content (%) + 26.81 crude protien yeild (q ha$^{-1}$)

The coefficient of determination ($R^2$) at 0.64 signifies a well-fitted model, indicating that the explanatory variables explain 64 per cent of the observed variation in green forage yields (Table 7). With the exception of crude fiber, ash, carbohydrates and crude protein content, all variables demonstrated statistically significant relationships.

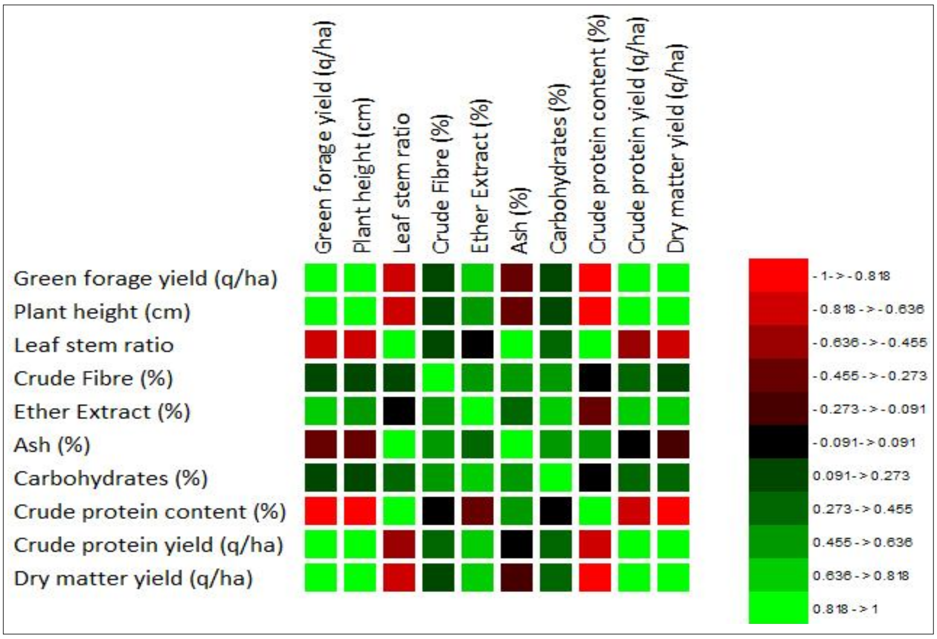


**Fig 1:** Correlation matrix between green fodder yield and plant characteristics of cowpea-maize system.

**Table 6:** Correlation between fodder yield and plant characteristics fodder cowpea-maize system (Pooled data).

| Variables | Green forage yield (q/ha) | Plant height (cm) | Leaf stem ratio | Crude fibre (%) | Ether extract (%) | Ash (%) | Carbohydrates (%) | Crude protein content (%) | Crude protein yield (q/ha) | Dry matter yield (q/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| Green forage yield (q/ha) | 1 | | | | | | | | | |
| Plant height (cm) | 0.98 | 1 | | | | | | | | |
| Leaf stem ratio | -0.74 | -0.78 | 1 | | | | | | | |
| Crude fibre (%) | 0.24 | 0.23 | 0.20 | 1 | | | | | | |
| Ether extract (%) | 0.64 | 0.59 | -0.03 | 0.60 | 1 | | | | | |
| Ash (%) | -0.32 | -0.38 | 0.83 | 0.47 | 0.42 | 1 | | | | |
| Carbohydrates (%) | 0.25 | 0.22 | 0.32 | 0.51 | 0.68 | 0.60 | 1 | | | |
| Crude protein content (%) | -0.89 | -0.92 | 0.88 | -0.09 | -0.43 | 0.56 | 0.02 | 1 | | |
| Crude protein yield (q/ha) | 0.93 | 0.88 | -0.48 | 0.32 | 0.77 | -0.02 | 0.44 | -0.69 | 1 | |
| Dry matter yield (q/ha) | 0.99 | 0.98 | -0.69 | 0.24 | 0.67 | -0.26 | 0.31 | -0.85 | 0.95 | 1 |

Specifically, the slope coefficient for plant height suggests that for every one-unit increase, we can anticipate a substantial 0.37 unit rise in fodder yield, assuming all other variables remain constant. Similarly, a one-percent increment in ether extract and crude protein yield results in increases of 28.70 and 26.81 units in fodder yield, respectively (Ajaykumar *et al*., 2022). Conversely, a one-percent increase in leaf stem ratio leads to a decrease in fodder yield by 240.8 units. This compelling econometric evidence underscores the significant impact of variables such as plant height, leaf stem ratio, ether extract and crude protein.

Our regression model allowed us to estimate the predicted fodder yield, which we compared against field-level fodder yield (Fig 2). Additionally, we examined

**Table 7:** Multiple linear regression analysis of the fodder cowpea and maize yield.

| Source | Coefficient | Standard error | t | Pr > \|t\| | Signification codes |
|---|---|---|---|---|---|
| Intercept | -4.07 | 40.41 | -0.10 | 0.92 | NS |
| Plant height (cm) | 0.38 | 0.12 | 3.09 | 0.01 | ** |
| Leaf stem ratio | -240.84 | 52.38 | -4.60 | 0.00 | *** |
| Crude fibre (%) | 2.51 | 1.48 | 1.69 | 0.11 | NS |
| Ether extract (%) | 28.71 | 12.34 | 2.33 | 0.03 | ** |
| Ash (%) | 1.09 | 4.29 | 0.25 | 0.80 | NS |
| Carbohydrates (%) | 0.42 | 1.35 | 0.31 | 0.76 | NS |
| Crude protein content (%) | -1.86 | 1.24 | -1.50 | 0.15 | NS |
| Crude protein yield (q/ha) | 26.82 | 2.59 | 10.37 | 0.00 | *** |

Note: **,*** and NS indicates significance at 5%, 1% level and non-significant, respectively.

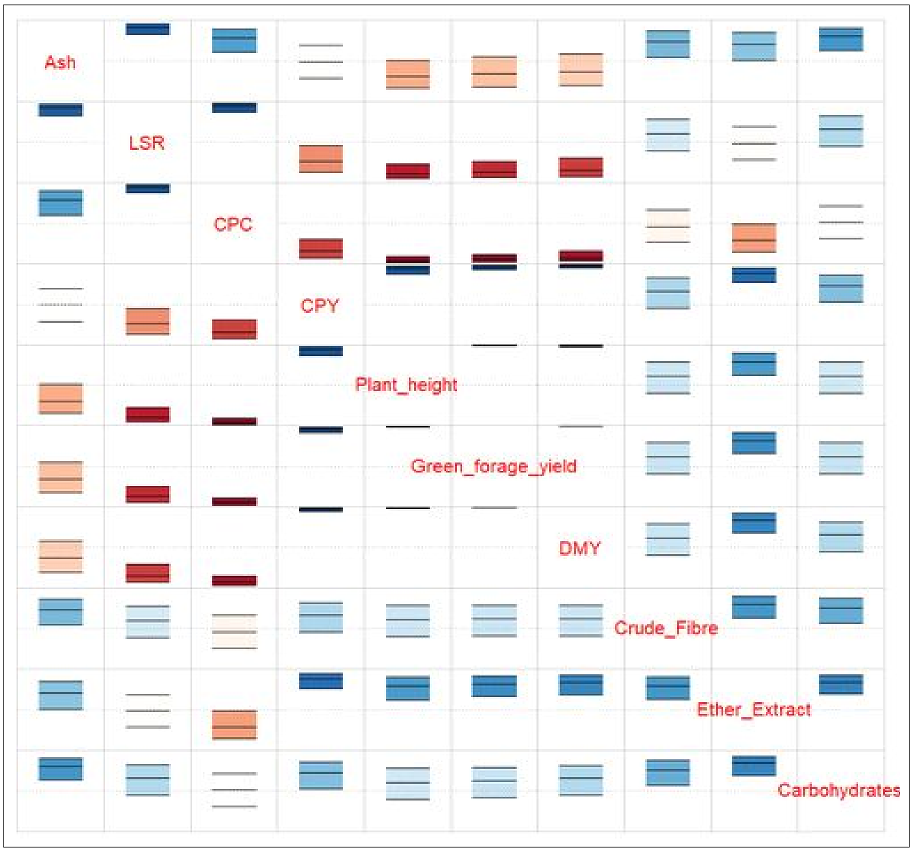


**Fig 2:** Visualization of correlation confidence interval of green fodder yield and plant characteristics of cowpea-maize system.

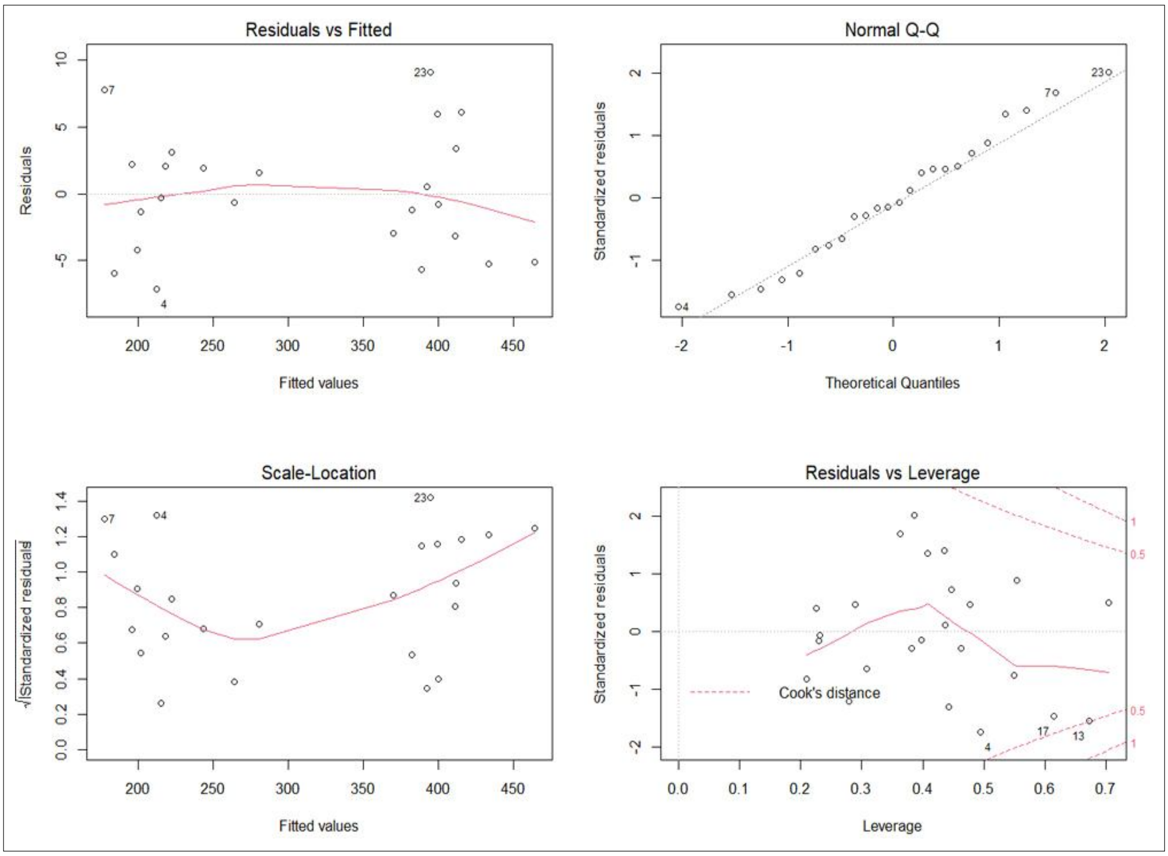


**Fig 3:** Regression diagnostic plots of green forage yield of cowpea-maize system.

regression diagnostic plots to assess the model's validity. These plots, including residual vs. fitted values, normal quantile-quantile (Q-Q) plots, scale-location plots and residuals vs. leverage values, consistently show that the model maintains constant error variance, adheres to normal distribution assumptions and is free from outliers (Fig 3). These observations reinforce the reliability of our statistical model in analyzing and predicting fodder yield.

## CONCLUSION

The outcomes of the three-year study indicate that the application of 50%RDN through FYM + 50% RDN through vermicompost significantly enhanced growth characteristics, quality parameters, yield attributes and overall yield compared to all other treatments. A comprehensive econometric analysis of plant attributes and their interrelationships reveals notable positive correlations and negative influences on green forage yield. Therefore, it is recommended that application of FYM and vermicompost and 50% RDN found better source of organic nutrients for achieving sustainable and economical fodder yield with quality in fodder cowpea-maize cropping system.

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### Conflict of interest

All authors declare that they have no conflicts of interest.

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