**Effect of Green Manuring and Nutrient Management on Soil Fertility, Growth and Yield Sustainability of Assam Lemon (*Citrus limon* L. Burm.) Orchards**

**ABSTRACT**

An experiment was carried out at AAU- Citrus and Plantation Crops Research Station, Tinsukia during 2020-2023 to evaluate the efficiency of the use of green manures on Assam Lemonin comparison to Farm Yard Manure (FYM) and inorganic fertilizers. The experiment was conducted withfive treatments *viz*.recommended dose of fertilizer (RDF) as control, green manuring (*Tephrosia*sp), green manuring with 50% RDF, FYM @20 kg/plant and FYM @20 kg/plant with 50% RDF and all the treatments were replicated thrice. Green manuring with 50% of RDF recorded the highest yield (21.35 t ha-1) along with higher values of all the yield parameters*viz.* number of fruits per plant (98.0) and fruit weight (196.12 g). However, the plant growth parameters did not show any significant difference among RDF, green manuring with 50% RDF and application of FYM with 50% RDF. Fruit volume, fruit juice content and ascorbic acid content were found significantly higher in green manured treatments. The soil properties after one year of application of green manuring with 50 % RDF showed significantly higher soil organic carbon, available nutrients (N, P, K) and water holding capacities over RDF, green manuring alone as well as application of FYM.

*Key words: Assam lemon, green manure, FYM, fruit quality*

**INTRODUCTION**

Assam Lemon (*Citrus limon* L. Burm.) is a distinctive kind of lemon cultivated exclusively in select regions of India, with Assam leading in both area and production. It is grown in the backyards of almost every household of the state without much significant productive measures taken for it. Assam lemon, also known as ‘Kajinemu’ or ‘Nemutenga’, which is an indigenous lemon of Assam (Bhattacharya and Dutta, 1956) and has a certain uniqueness in terms of quality that is primarily attributable to its place of origin namely Assam. Besides, Assam Lemon is the proud beholder of a number of other useful characteristics like aroma, medicinal value and so on. In Assam, lemon and lime cover around 15.90 thousand hectares and produce 157.32 thousand metric tonnes, with a total citrus production of 369.56 thousand metric tonnes (Anonymous, 2022).

Farmers in North Eastern India have been growing Assam lemon through traditional methods for generations, relying solely on natural practices without the use of chemical fertilizers. Despite this rich legacy, research into the organic cultivation of Assam lemon remains limited. To ensure its sustainable production, there is a pressing need to standardize organic nutrient management practices. Among these, green manuring holds significant promise for boosting yields and maintaining soil fertility—yet it remains an underexplored area in citrus orchard management.Incorporating green manure is a key pillar of organic and sustainable agriculture. Its use in orchards offers a wide range of ecosystem benefits—from controlling soil erosion and reducing nutrient leaching to enhancing soil carbon sequestration and nutrient availability. Additionally, green manure fosters greater soil microbial diversity while naturally suppressing pests and weeds, contributing to a healthier and more resilient farming system (Adetunji, *et al.*, 2020, Kim, *et. al*., 2020, Wang *et al*., 2022).*Tephrosia candida*, commonly known as the white hoary pea, belonging to the Leguminosae family is widely used as a perennial green manure crop in orchards. The leaf biomass of *Tephrosia candida* contains significantly higher levels of essential nutrients, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca2+), and micronutrients (Ali et.al., 2023)

In response to the growing demand for organic fruit production using locally available organic inputs, the present study was carried out at the AAU-Citrus and Plantation Crops Research Station, Tinsukia, during 2022–2024. The research aimed to evaluate the effectiveness of green manure (Tephrosia candida) in comparison to farmyard manure (FYM) and inorganic fertilizers on growth, yield, and fruit quality of Assam lemon.

**MATERIALS AND METHODS**

A field experiment was conducted at the experimental research farm of the AAU-Citrus and Plantation Crops Research Station in Tinsukia, Assam, India. The soil at the site is classified under the Indo-Gangetic alluvial group, characterized by a sandy loam texture and good drainage. The study was carried out during 2022–2024 using a randomized block design with four replications. Four-year-old Assam lemon trees, spaced at 3 × 3 meters, were selected for the experiment.

The treatments consisted of T1-Recommended Dose of Fertilizer (RDF), T2-Green Manuring (GM) with *Tephrosia candida*, T3-Green manuring (*Tephrosia candida)* + 50% RDF, T4 –FYM and T5- FYM + 50% RDF. The recommended doses of NPK were applied as 600 g N + 400 g P2O5 + 580 g K2O / tree each year in the form of urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. FYM was applied @ 20 kg / plant each year within the tree basin. GM crop *Tephresia candida* was sown during rainy season and allowed to grow up to 75 days after sowing and the above ground part was cut at the height of the root collar and left on the soil surface (without soil turnover). Need based crop protection measures for pest and diseasecontrols were applied throughout the crop period. Harvesting was done from 3rd week of July to 1st week of October and fruit yield was recorded per tree basis.

Soil samples were collected prior to layout of the experiment and after harvesting of fruit for from 0-15 cm depth, within the tree basin using a soil augur. Soil analysis (water holding capacity, soil pH, soilorganic carbon, available N, P and K) was performed as per standard procedures.

For fruit quality analysis, ten fruits were randomly collected from each treatment replication wise and acidity, ascorbic acid, TSS were estimated as per the standard procedures of Ranganna (1986). The data was analyzed by standard analysis of variance (ANOVA). Univariate statistical analysis and significance was concluded using SPSS and Microsoft-Excel software.

**RESULTS AND DISCUSSION**

Soil physico-chemical properties

The results of the present study indicated that the soil organic carbon (SOC) content was significantly influenced by different treatments over the periods of experimentation. SOC in the top soil layer (0-15 cm) varied between 0.58 to 0.78 % across different treatments with the highest value of 0.78% in T3(Table 1). Improvement in SOC content was noticed in NPK+GM (T3) as compared to sole application of GM and control (T1). In general, there was a significant increase in the level of soil organic carbon under various integrated nutrient management modules which may be attributed to the positive effect of green manuring/FYM in presence of chemical fertilizer leading to formation of optimum stable aggregates and therefore higher organic carbon content in soil (Kumar *et. al*., 2017*).*The application of FYM or green manure (GM) enhanced the decomposition of complex organic matter, leading to its transformation into mineralized organic colloids that enriched the soil organic carbon pool.

It has been reported by several workers that addition of organic sources and/or long term integrated nutrient management improved SOC content (Rudrappa*et al*., 2006). The highest average available N content was recorded as 315.20 kgha-1and 346.70 kg ha-1in T5 and T3 respectively which were significantly higher than other treatments (Table 1). Similarly, addition of FYM and GM along with NPK had improved P and K content. Green manure crops accumulate large amount of P and upon decomposition form bicarbonates (H2CO3) resulting solubilization of soil mineral P and makes the phosphorus sufficiency for the companion crops(Tissen et al., 1994).

Thus, the application of *Tephrosia* biomass as mulch enriches the soil with essential nutrients, particularly nitrogen, phosphorus, and potassium. This process is facilitated by the release of organic acids during biomass decomposition, which minimizes nutrient fixation and enhances nutrient availability in the soil (Ali *et al*., 2024). Similar improvement in soil fertility status after incorporating organic sources *viz*., green manuring or FYM or compost was also reported by Albiach*et al*. (2001).

Green manuring and application of FYM showed significant increase in water holding capacity of soil with the highest value in green manuring alone (54.87%) and lowest in treatment receiving chemical fertilizers only (46.16 %). Improvement in water holding capacity may be because of increased total pore space and organic matter due to incorporation of green manure/FYM. Similarly, Biswas *et al*. (1971) observed reduction in bulk density and improvement in pore space and water holding capacity in soil after incorporation of manures and/or green manure. Similarly, Fuchs and Hadas (2011), found that a thicker mulching layer significantly increases water storage capacity, reducing runoff and enhancing resistance to water vapour, thus the quantity of mulch applied improved water retention.

Green manuring of leguminous crops results in accumulation of organic matter on the soil surface, cycling of nutrients by means of biological fixation, improvement of the chemical and physical attributes of the soil and greater water retention and infiltration capacity.Thus, the use of green manure in sustaining soil health can be viewed as an important soil management strategy to increase soil organic matter and maintaining optimum nutrients levels for quality fruit production. The accumulation of nutrients, especially N, P and K in soil may largely replace the need for supplying nutrients through chemical fertilization.

Table. 1. Effect of green manuring and organic manures on soil properties in Assam lemon

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatment | WHC (%) | pH | Organic Carbon (%) | Available N(kg ha-1) | Available P2O5 (kg ha-1) | Available K2O(kgha-1) |
| T1 :100%NPK | 46.16 | 4.98 | 0.58 | 265.88 | 13.43 | 152.86 |
| T2 : Green manuring (*Tephrosia*sp) | 53.87 | 5.11 | 0.77 | 292.25 | 14.52 | 147.36 |
| T3 : Green manuring+ 50% NPK | 53.26 | 5.09 | 0.79 | 336.70 | 15.34 | 167.11 |
| T4 : FYM @ 20 kg/plant | 50.53 | 5.01 | 0.69 | 282.25 | 13.02 | 143.66 |
| T5 : FYM+ 50% NPK | 49.72 | 4.98 | 0.67 | 305.20 | 14.10 | 168.4 |
| S.Ed(±) | 1.34 | - | 0.03 | 6.16 | 0.41 | - |
| CD (0.05) | 4.05 | NS | 0.08 | 23.12 | 1.06 | NS |
| *Initial values* | *47.26* | *5.02* | *0.61* | *246.83* | *12.32* | *161.57* |

**Vegetative Growth Parameters**

The application of green manure and FYM or combined application of organic manures and chemical fertilizers showed significant influence on the plant vegetative growth characters (Table 2). Maximum mean increment in plant height (15.10%), stem girth (4.82%) and canopy volume(18.52%) were observed in treatment T3 (Green manuring + 50% NPK) followed by combined application of FYM and 50% RDF which are at par with the application of RDF. However, significantly lower vegetative growth was recorded in T2 and T3*i.e.* application of green manure and FYM alone.

Different combinations of organic fertilizers along with urea as inorganic fertilizer were earlier reported to result in increased canopy volume and girth of Coorg mandarin (Mustaffa *et al.* 1997).The improvements in plant growth parameters of Assam lemon with *Tephrosia* biomass mulching can be attributed to the improvement in soil fertility, as evidenced by increased soil nutrient and soil moisture retention (Haokip et al., 2021). Das et. al. (2021) also reported a better tree height, trunk diameter under *Tephrosia* treatments under bael orchard.

Table. 2. Effect of green manuring and organic manures on growth of Assam lemon

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Plant height  | Stem girth | Canopy volume |
|  | Initial (cm) | Final(cm) | Increase (%) | Initial (cm) | Final(cm) | Increase (%) | Initial(m3) | Final(m3) | Increase (%) |
| T1 | 124.5 | 142.0 | 14.1 | 11.46 | 12.08 | 5.41 | 1.41 | 1.60 | 13.47 |
| T2 | 120.6 | 134.3 | 11.4 | 11.51 | 11.86 | 3.04 | 1.38 | 1.52 | 10.14 |
| T3 | 126.2 | 145.2 | 15.1 | 11.83 | 12.40 | 4.82 | 1.62 | 1.92 | 18.52 |
| T4 | 122.1 | 136.9 | 12.1 | 11.34 | 11.68 | 2.99 | 1.53 | 1.70 | 11.11 |
| T5 | 128.2 | 147.2 | 14.8 | 11.72 | 12.20 | 4.09 | 1.57 | 1.84 | 17.19 |
| S.Ed(±) | - | 3.54 | 0.32 | - | 0.72 | 0.51 | - | 0.05 | 1.04 |
| CD (0.05) | - | NS | 1.2 | - | NS | 1.32 | - | 0.19 | 3.04 |

**Fruit quality Parameters**

The application of organic manures caused significant variation on the physical parameters of the fruits. The maximum fruit weight (196.12 g) and fruit volume (191.33 cc) was recorded in treatment T3 while the minimum fruit weight (158.45g) and fruit volume (160.35 cc) was recorded in T2. In case of the quality parameters, the treatment T3(Green manuring + 50% NPK) showed the maximum TSS (6.00B), ascorbic acid (35.76 mg/100 ml juice) and juice content (49.07%). Ascorbic acid, content juice content and TSS were significantly different among the treatments while no significant variation was found in titratable acidity (Table 3).

Green manuring and application of FYM combined with NPK increases the uptake and translocation of nutrients which leads to the increase in the photosynthetic ability and carbohydrate supply and thereby increases the weight and size of the fruits. The application of green manuring by increasing the availability, uptake and translocation of plant nutrients, especially nitrogen, might lead to the synthesis of organic acids in fruits and increased ascorbic acid content in fruits (Chaudhary *et. al*, 2024). Similarly, increased availability of nutrients, improved soil aeration, stimulated cell division, cell elongation, and better translocation of water uptake and deposition of nutrients in treatments with green manure leads to an increase in dry matter and total soluble solids of the fruits. Kumar *et al*. (2017) also observed significant improvements in mango cultivation when utilizing green manure from sun hemp, combined with farmyard manure and NPK.

Table. 3. Effect of green manure and organic manures on fruit quality of Assam lemon

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | Fruit wt(g) | Fruit volume (cc) | Thickness of albedo (mm) | Juice content % | TSS (0Brix) | Ascorbic acid (mg/100 ml juice | Titratable Acidity (%) |
| T1 | 174.37 | 171.46 | 3.86 | 32.24 | 5.4 | 33.12 | 3.70 |
| T2 | 158.45 | 160.35 | 3.57 | 33.56 | 5.6 | 32.55 | 3.62 |
| T3 | 196.12 | 191.33 | 5.02 | 49.07 | 6.0 | 35.76 | 2.92 |
| T4 | 164.27 | 161.07 | 3.80 | 38.26 | 5.8 | 33.17 | 3.40 |
| T5 | 179.34 | 175.26 | 4.29 | 46.33 | 6.0 | 34.65 | 2.98 |
| S.Ed(±) | 3.36 | 4.02 | 0.27 | 1.01 | 0.12 | 0.54 | 0.22 |
| CD (0.05) | 11.24 | 12.44 | 0.92 | 3.7 | 0.42 | 1.8 | 0.62 |

**Effect of organic manures on yield and yield attributes:**

The application of Green manuring + 50% NPK (T3) recorded higher values for no. of fruits per plant (98.0), fruit weight (196.12g), and yield (21.35t/ha) followed by application of FYM + 50% NPK (T5) and inorganic fertilizer alone (T1)where as the lowest (11.41t/ha) yield has been recorded in T2 (Table 4.). The higher fruit yield in treatments with combination of organic manures *i.e.* green manure and FYM with inorganic fertilizers (T3 and T5) could be attributed to slow and sustained release of nutrients from the incorporated green manures as well as FYM( Irin and Biswas, 2023). As a result the entire nitrogen becomes available to the plant over an extended period of time (Naidu, 2021).The increased fruit yield under green manuring treatment can also be attributed to enhanced soil chemical and physical properties, a more balanced C/N ratio, and a higher availability of essential nutrients that support key physiological processes (Phukan *et al*., 2016).

Similar to the present study, Ghosh and Besra (1997) observed the highest fruit yield and improved quality with 25 kg organic matter in combination with inorganic fertilizers in sweet orange grown in acid red soil under the humid tropical climate of northeast India.

Table. 4. Effect of green manuring and organic manures on yield of Assam lemon

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Fruits/plant | Yieldkg/plant | Yieldt/ha |
| T1 | 81.0 | 14.12 | 15.69 |
| T2 | 72.3 | 11.41 | 12.68 |
| T3 | 98.2 | 19.22 | 21.35 |
| T4 | 78.5 | 12.81 | 14.23 |
| T5 | 93.1 | 16.68 | 18.53 |
| S.Ed(±) | 2.87 | 1.42 | 1.34 |
| CD (0.05) | 9.04 | 3.23 | 3.86 |

**CONCLUSIONS**

The study concluded that the application of green manure (Tephrosia sp.), farmyard manure (FYM), and inorganic fertilizers significantly improved the soil physico-chemical properties and productivity indices in Assam lemon orchards. Green manuring notably increased soil organic carbon and water holding capacity compared to the control. The highest yield (21.35 t ha-1) was achieved when green manure was combined with 50% of the recommended dose of fertilizers (RDF), outperforming treatments using green manure alone (12.68 t ha⁻¹) or RDF alone (15.69 t ha⁻¹). Intercropping and the incorporation of green manure along with inorganic fertilizers created synergistic effects, enhancing both yield and quality beyond the individual contributions of each input. Therefore, integrating green manuring with a reduced NPK dose presents a sustainable and effective strategy for managing Assam lemon orchards.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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