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Effect Of Leaf Nutrient On Balanced Flowering In Neem

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INTRODUCTION

Neem (Indian Lilac) is an evergreen tree native to the Indian subcontinent and Southeast Asia. It can reach a height of up to 20 meters. Neem can thrive in various soil types, including clay, sand, saline, and alkaline soils. It grows best in regions with temperatures ranging from 21 to 32°C but is sensitive to frost. Revered for its medicinal properties, neem is known as 'Nimba' in Sanskrit, meaning 'reliever of sickness,' and 'Sarbarogaribarini' and 'Azad-Darakth-E-Hind' in Persian. The tree is known to contain over 140 bioactive compounds, such as nimbin, nimbidin, azadirachtin, and gedunin, which have been shown to possess antimicrobial, anti-inflammatory, and antioxidant properties. Neem trees flower between February and May, with regional variations across India. In northern India, flowering begins 2-5 weeks later than in the southern regions. In southern India, new leaves and inflorescence primordia emerge simultaneously in February and March. Flowering peaks in the third week of April, with fruits observed two weeks later, maturing by the third week of June. Fruits fall in late July and germinate with the onset of the monsoon.

The transition from the vegetative to the reproductive phase in plants is a critical process, especially in forestry and horticulture, as it directly impacts productivity and yield. In perennial tree species like neem, the flowering process is influenced by several intrinsic and extrinsic factors, including age, photoperiod, temperature, pruning, and nutrient availability. Among these, the physiological and biochemical status of the leaves plays a pivotal role in signaling and sustaining reproductive development. Leaf nutrients not only support basic metabolic functions but also contribute to the synthesis of growth regulators and floral hormones. For instance, nitrogen aids in protein and nucleic acid synthesis, while phosphorus is crucial for energy transfer and signaling pathways. Potassium supports enzyme activity and sugar translocation, which are essential during flowering and fruit setting. Recent advancements in plant physiology have made it possible to quantify leaf-level traits such as chlorophyll content, carbohydrate concentration, and protein levels, which correlate with floral intensity. Non-destructive tools like the Chlorophyll Content Index (CCI) and the Chlorophyll to Carotenoid Ratio (CCR) offer practical means to monitor plant health and flowering readiness in real-time.

In this context, understanding the relationship between leaf nutrient composition and flowering intensity in neem trees is not only scientifically valuable but also highly applicable in plantation management. By identifying the key nutritional drivers of flowering, this research aims to provide insight into how nutrient dynamics can be optimized to enhance reproductive performance, ultimately improving seed yield and the ecological sustainability of neem-based agroforestry systems.

2. Materials and Methods

This study was conducted on *Azadirachta indica* trees aged six years, grown under uniform field conditions. The trees selected were in the active flowering phase and had been managed with standard agronomic practices. Leaf samples were collected during peak flowering to assess the nutrient status and physiological traits related to reproductive performance. Fully expanded, healthy leaves were harvested from the mid-canopy region of each tree. The collected leaves were immediately transported to the laboratory, washed with distilled water, and dried for further biochemical analysis. Parameters analyzed included total nitrogen (TN), total phosphorus (TP), total potassium (TK), chlorophyll a (C_a), chlorophyll b (C_β), total chlorophyll (C_t), chlorophyll ratio (C_r), soluble protein (SP), total carbohydrates (TC), carotenoids (CR), C/N ratio (C/N), Chlorophyll Content Index (CCI), and Chlorophyll to Carotenoid Ratio (CCR). Flowering was quantified as the average number of flowers per tree.

All statistical analyses were performed using R software (version RStudio 2022.07.2), and a correlation matrix was generated using the corrplot package to determine the strength and direction of relationships between leaf nutrient parameters and flowering.

3. Results and Discussion

The correlation matrix presented in Figure 1 provides a comprehensive visual representation of the relationships between various leaf nutrient parameters and flowering in six-year-old *Azadirachta indica* (neem) trees. The correlation coefficients, indicated by the intensity of red shading, reveal that flowering (FLO) is positively associated with nearly all the measured variables. This indicates that higher levels of certain nutrients and physiological indicators in the leaves strongly support the reproductive performance of neem trees.

3.1. Strong Positive Correlations with Flowering

Among the measured variables, **Chlorophyll Content Index (CCI)** and **Chlorophyll to Carotenoid Ratio (CCR)** showed the **strongest positive correlation** with flowering. This suggests that neem trees with a higher chlorophyll concentration and a greater ratio of chlorophyll to carotenoids are more likely to exhibit enhanced flowering.

- **CCI** is a direct indicator of the photosynthetic capacity of a leaf. Leaves with higher chlorophyll content can absorb more light energy, driving photosynthesis more efficiently. This energy surplus is crucial for the energy-intensive process of flowering and fruit setting.
- **CCR**, or the chlorophyll-to-carotenoid ratio, reflects the balance between light-capturing pigments (chlorophyll) and photoprotective pigments (carotenoids). A higher CCR implies optimal light harvesting with minimal oxidative stress, enabling plants to allocate more resources toward reproductive development.

3.2. Nutrient Uptake and Reproductive Response

The macronutrients **Total Nitrogen (TN), Total Phosphorus (TP), and Total Potassium (TK)** were all positively correlated with flowering. These nutrients are essential drivers of plant metabolism and play distinct roles in floral induction:

- **Nitrogen (TN)** is a major component of amino acids, proteins, and nucleic acids. Higher nitrogen content in leaves promotes vigorous growth and the synthesis of flowering hormones like cytokinins and gibberellins.
- **Phosphorus (TP)** is vital for energy transfer in the form of ATP and for the synthesis of nucleic acids. It facilitates flower initiation and enhances root-to-shoot nutrient signaling.
- **Potassium (TK)** regulates osmotic balance and enzyme activation. It plays a key role in sugar transport and turgor regulation, which are essential for flower and fruit development.

3.3. Photosynthetic Pigments and Flowering

A clear positive trend was observed between flowering and the various chlorophyll fractions—**Chlorophyll a (C_a), Chlorophyll b (C_β),** and **Total Chlorophyll (C_t).** These pigments are integral to the photosynthetic apparatus, and their abundance indicates robust energy capture and conversion efficiency in the leaf. Interestingly, the **chlorophyll ratio (C_r)**—the proportion between Chlorophyll a and b—also correlated positively with flowering. This implies that not only the quantity but also the qualitative balance of pigments influences flowering potential.

3.4. 4Biochemical Parameters and Flowering

- **Soluble Protein (SP)** content in leaves also showed a positive correlation with flowering. Proteins are essential for enzymatic activities, metabolic regulation, and signaling processes that initiate and sustain floral growth.

- **Total Carbohydrates (TC)** demonstrated a positive relationship with flowering, supporting the hypothesis that carbohydrate accumulation in leaves is a key prerequisite for floral induction. These carbohydrates serve as both an energy source and a signaling molecule for developmental transitions.

- The **C/N ratio**, which represents the balance between carbon (as carbohydrates) and nitrogen (as proteins and amino acids), also correlated positively with flowering. A favorable C/N ratio has been reported to trigger flowering in several perennial species by indicating a surplus of stored carbon ready for reproductive investment.

CONCLUSION

The study highlights a strong relationship between leaf nutrient status and flowering in neem trees. Key parameters like nitrogen, phosphorus, potassium, chlorophyll content, and CCI and CCR values showed positive correlations with flowering intensity. These findings suggest that maintaining optimal leaf nutrition can significantly enhance the reproductive performance of neem, offering practical benefits for sustainable plantation and forest management.

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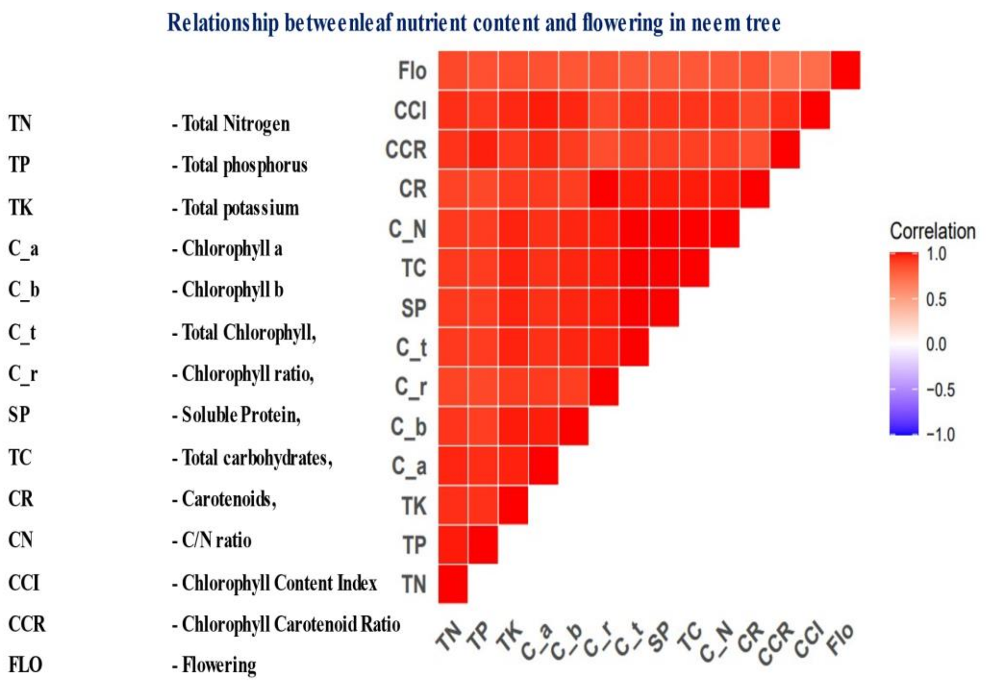

Table 1. Flowering and leaf Nutrient Contents