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# Innovative Nutrient Integration Techniques for Improved Sugarcane Production under Calcareous Soil of Bihar

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## Introduction:

Sugarcane (*Saccharum officinarum* L.) is a significant crop in Bihar, providing a critical source of income and employment for the rural population. Bihar's calcareous soils, which are characterized by high calcium carbonate content, present unique challenges and opportunities for sugarcane cultivation. These soils often exhibit poor nutrient availability, especially for micronutrients and can impede crop productivity. Integrated Nutrient Management (INM) offers a comprehensive approach to addressing these challenges, combining organic and inorganic nutrient sources to enhance soil fertility and crop yield sustainably (Kumar *et al.*, 2024).

## Characteristics of Calcareous Soils in Bihar

Calcareous soils, prevalent in many parts of Bihar, contain high levels of calcium carbonate, which can significantly influence nutrient dynamics and availability. These soils typically exhibit:

1. **High pH Levels**: The pH of calcareous soils generally ranges between 7.5 and 8.5, which can reduce the availability of essential nutrients like phosphorus, iron, zinc, and manganese.
2. **Nutrient Imbalances**: The presence of calcium carbonate can lead to the precipitation of phosphates and micronutrients, making them less accessible to plants.
3. **Poor Organic Matter Content**: Calcareous soils often have low organic matter, which affects soil structure, water retention, and microbial activity. (Zade et al., 2021).

Given these constraints, effective nutrient management strategies are crucial for optimizing sugarcane production in these soils.

## Principles of Integrated Nutrient Management

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INM involves the judicious use of chemical fertilizers in combination with organic amendments and bio-fertilizers to achieve balanced nutrient supply. The key principles of INM include:

1. **Soil Testing and Analysis**: Regular soil testing to determine nutrient status and tailor nutrient applications accordingly (Meena et. al., 2024).
2. **Balanced Fertilization**: Ensuring the appropriate proportions of macronutrients (N, P, K) and micronutrients (Fe, Zn, Mn, etc.) are applied (Kumar et. al., 2023).
3. **Use of Organic Amendments**: Incorporating organic manures, compost, and green manures to improve soil organic matter and enhance nutrient availability (Sinha et al., 2024).
4. **Bio-fertilizers**: Utilizing microbial inoculants that can fix atmospheric nitrogen, solubilize phosphates, and mobilize other nutrients.
5. **Crop Residue Management**: Recycling crop residues to maintain soil organic matter and nutrient levels.

**Components of Integrated Nutrient Management in Sugarcane**

1. **Chemical Fertilizers**: Chemical fertilizers provide readily available nutrients to the crop. The recommended doses for sugarcane in Bihar typically include nitrogen (N), phosphorus (P), and potassium (K) in the ratios of 150:60:40 kg/ha, respectively. However, these recommendations should be adjusted based on soil test results.
2. **Organic Manures**: Organic manures such as farmyard manure (FYM), compost, and vermicompost improve soil structure, water-holding capacity, and microbial activity. The application of 10-20 tons/ha of FYM or compost is recommended to enhance soil fertility.
3. **Green Manuring**: Green manure crops like Sesbania and Sunn hemp can be grown and incorporated into the soil before sugarcane planting. These crops add organic matter and nutrients, particularly nitrogen, to the soil.
4. **Bio-fertilizers**: Bio-fertilizers such as *Acetobacter*, *Azospirillum*, *Azotobacter*, and phosphate-solubilizing bacteria (PSB) play a vital role in nutrient cycling and availability. Inoculating sugarcane setts with these bio-fertilizers can enhance nitrogen fixation and phosphorus solubilization (Kumar et. al., 2024a).
5. **Micronutrient Management**: Given the high pH and calcium carbonate content of calcareous soils, the

availability of micronutrients like zinc, iron, and manganese is often limited. Foliar application of these micronutrients or soil application of chelated forms can address deficiencies effectively.

6. **Irrigation Management**: Efficient water management is essential for nutrient uptake. In calcareous soils, maintaining optimal soil moisture levels helps in nutrient solubility and availability. Drip irrigation can be particularly effective in ensuring uniform nutrient distribution and water use efficiency.

**Implementation Strategies for INM in Sugarcane**

1. **Soil Testing and Custom Fertilization Plans**: Farmers should conduct regular soil tests to monitor nutrient levels and adjust fertilization plans accordingly. Customized fertilizer recommendations based on soil test results can prevent nutrient imbalances and optimize crop growth (Meena *et. al.,* 2023).
2. **Integration of Organic and Inorganic Nutrients**: Combining organic manures with chemical fertilizers can enhance nutrient availability and improve soil health. For instance, applying FYM along with recommended doses of NPK fertilizers can provide a balanced nutrient supply and improve soil structure.
3. **Use of Bio-fertilizers and Microbial Inoculants**: Bio-fertilizers should be incorporated into the planting process. For example, treating sugarcane setts with Azospirillum and PSB before planting can improve nitrogen fixation and phosphorus solubilization (Kumar et. al., 2024a).
4. **Micronutrient Management through Foliar Application**: Foliar sprays of micronutrients can be used to quickly correct deficiencies. For instance, applying 0.5% zinc sulfate or 0.1% iron sulfate solutions as foliar sprays can address zinc and iron deficiencies in sugarcane (Kumar et. al., 2024b).
5. **Crop Residue Management**: Incorporating sugarcane trash and other crop residues into the soil can enhance organic matter content and nutrient cycling. Practices such as trash mulching can also help conserve soil moisture and reduce soil erosion (Singh et al., 2022).
6. **Adoption of Drip Irrigation Systems**: Drip irrigation can ensure efficient water and nutrient delivery to the root zone, reducing nutrient losses and improving nutrient use efficiency.

Fertigation, or the application of fertilizers through the irrigation system, can provide a precise and timely nutrient supply to the crop.

**Benefits of Integrated Nutrient Management**

1. **Enhanced Soil Fertility**: INM practices improve soil physical, chemical, and biological properties, leading to better soil health and fertility.
2. **Sustainable Crop Yields**: By providing balanced and adequate nutrient supply, INM ensures sustainable and high sugarcane yields.
3. **Reduced Environmental Impact**: INM minimizes nutrient losses through leaching and runoff, reducing the environmental footprint of sugarcane cultivation (Kumar at al., 2024c).
4. **Cost-Effective**: The combined use of organic and inorganic fertilizers can be more cost-effective than relying solely on chemical fertilizers, reducing input costs for farmers.
5. **Improved Soil Health**: The addition of organic matter and microbial inoculants enhances soil microbial activity and biodiversity, contributing to long-term soil health.

**Challenges and Future Directions**

Despite the benefits, several challenges need to be addressed to optimize INM in sugarcane cultivation under calcareous soils:

1. **Awareness and Training**: Farmers need to be educated about the benefits of INM and trained in its implementation. Extension services and farmer training programs can play a crucial role in this regard.
2. **Availability of Inputs**: Ensuring the availability of quality organic manures, bio-fertilizers, and micronutrient formulations is essential for the successful adoption of INM practices.
3. **Research and Development**: Continued research is needed to develop region-specific INM strategies and recommendations. This includes studying the interactions between different nutrient sources and their effects on soil health and crop productivity.
4. **Policy Support**: Government policies and incentives can encourage the adoption of INM practices. Subsidies for organic inputs and bio-fertilizers, as well as support for soil testing infrastructure, can promote widespread adoption.

**Conclusion**

Integrated Nutrient Management offers a viable solution to the challenges of sugarcane

cultivation in calcareous soils of Bihar. By combining the use of chemical fertilizers, organic manures, and bio-fertilizers, INM enhances soil fertility, ensures balanced nutrient supply, and promotes sustainable crop yields. Implementing INM practices requires a collaborative effort involving farmers, extension services, researchers, and policymakers. With the right support and strategies, INM can significantly contribute to the productivity and sustainability of sugarcane cultivation in Bihar's calcareous soils.

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