



Strategies for Effective fertilization and nutrient management in sugarcane: Integrated nutrient management

Sunita Kumari Meena, Ajeet Kumar, Lalita Rana, S.N. Suman, A.K. Singh

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SOUVENIR CUM EDITED BOOK

Sustainable Sugarcane Production and Utilization: Issues and Initiatives

Editors: Navnit Kumar, A.K. Singh, D.N. Kamat, Anil Kumar,
Md. Minnatullah, Ajeet Kumar, S.N. Singh, C.K. Jha and Anupam Amitabh



Annual Group Meet - 2023

All India Coordinated Research Project on Sugarcane
(October 26 – 27, 2023)

Organized by:

Dr. Rajendra Prasad Central Agricultural University

Sugarcane Research Institute

Pusa (Samastipur)- 848125, Bihar

and

ICAR-Indian Institute of Sugarcane Research

Lucknow - 226 002



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Patron

Dr. P.S. Pandey, Vice-Chancellor, RPCAU, Pusa

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Strategies for Effective Fertilization and Nutrient Management in Sugarcane: Integrated Nutrient Management

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Introduction

One of the most significant cash crops, sugarcane plays a significant role in the national economy as a significant renewable energy source with the potential to spur industrialization in rural India. Over three lakh workers and technicians, together with about 25 million growers, are involved in the crop's processing and growing. In addition, a sizable number of people work in the sugar, khandsari, and gur industries. With an average productivity of 68 t/ha, it produces 350 million tons of grain annually on an area of around 5.0 million hectares in India. It has an area of roughly 2.5 hectares in Bihar with a productivity of 50–60 t ha⁻¹ on average. The average sugarcane productivity in the current decade is 60t/ha with a recovery of 9–10%. As a result, the applicability of a cropping system based on sugarcane has been seriously impacted by the plateauing of yield levels, deteriorating productivity, rising production costs, and declining monetary profit.

The secret to improving agricultural output by raising the productivity of the soil is fertilizer. It is also a way of conserving land, which is becoming a scarce resource in nations like India because to the growing ratio of people to land and the demand for food, fuel, and fiber. Inadequate, unbalanced, and heavily biased in favor of nitrogen fertilizer use in India has led to the rise of multinutrient deficits. The use of high analysis fertilizers results in the deficit of various micronutrients, and the lack of secondary and micronutrients has begun to limit the response to primary nutrients (NPK) (Shukla et al., 2022). Therefore, precautions must be made to prevent the imbalanced application of fertilizers to boost crop output, which could eventually enhance the condition of the soil and reduce environmental issues. As a source of nutrients, a source of metabolic energy for biological processes, and a contributor to soil health, soil organic matter is essential to ensuring long-term soil fertility. According to numerous studies, using the right mixtures of organic and inorganic nutrients boosted the effectiveness of fertilizer use and sugar yield. Because organic nutrition sources are few and unable to supply all the nutrients needed to maintain large-scale productivity targets, their combined usage with inorganic fertilizers has become unavoidable. Numerous studies on manures and fertilizers for sugarcane have shown that neither organic sources alone nor sugarcane alone can sustainably produce both soil and crop under very intensive farming systems (Singh et al., 2019). Consequently, comprehensive nutrient management would unquestionably aid in reaching the objective.

Integrated Nutrient Management

By maximizing all potential sources of plant nutrients in an integrated way, integrated nutrient management maintains soil fertility and plant nutrient delivery to an optimal level for sustaining intended crop yield. Improving and maintaining soil fertility is the major goal of integrated nutrient management in order to satisfy changing needs and provide a solid foundation for crop production systems. INM's fundamental tenet is the prudent and effective use of chemical fertilizers to maintain soil fertility, sustain agricultural production, and increase farmer profitability. It makes the most effective use of the farm's externally purchased inputs to maximize productivity and profitability while avoiding negative



environmental effects over an extended period of time. Therefore, combining the use of chemical fertilizers with the recycling of nutrients from organic waste can be a successful strategy to stop nutrient depletion and encourage sustained sugar productivity. There is a lot of potential for recycling back some organic wastes (such as pressmud, sugarcane trash, biocompost, distillery effluent, etc.) in soil in sugarcane growing areas, and integrated application of sugarcane waste may reduce the usage of chemical fertilizers and improve sugar productivity (Raza et al., 2021). In order to maximize fertilizer use effectiveness and boost crop output while reducing environmental impacts, one strategy called integrated nutrient management (INM) combines several nutrient sources and activities. It incorporates both sustainable agriculture techniques and a combination of organic and inorganic nutrient sources. INM should be viewed as a comprehensive strategy for soil and plant nutrition that takes into account a number of factors, including the following:

Different components or factors of INM

Soil Testing and Analysis:

Soil testing is the foundation of INM. It involves the analysis of soil samples to determine nutrient content, pH, and other relevant parameters. This information guides nutrient recommendations.

Balanced Nutrient Application:

The goal is to provide a balanced supply of essential nutrients, including macronutrients (nitrogen, phosphorus, potassium) and micronutrients (iron, zinc, etc.). The application rates and ratios are adjusted based on crop requirements and soil nutrient status.

Organic and Inorganic Fertilizers:

INM combines both organic and inorganic nutrient sources. Organic sources can include compost, farmyard manure, crop residues, and green manure. These improve soil health and organic matter content. Inorganic sources include synthetic fertilizers, such as urea, superphosphate, and muriate of potash.

Nutrient Timing:

Nutrients are applied at specific growth stages to match crop demand. For instance, nitrogen is often applied in split doses to coincide with critical growth phases.

Micronutrient Management:

INM takes into account the need for essential micronutrients like iron, zinc, and manganese, which are vital for crop growth and quality.

Crop Rotation and Diversification:

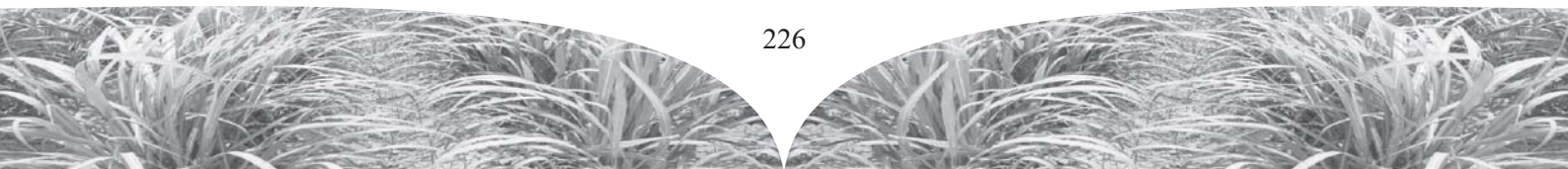
Crop rotation is an important component, as it can break disease cycles and improve soil health. Diversification includes growing a variety of crops to avoid nutrient depletion specific to a single crop.

Legumes and Green Manure Crops:

Leguminous crops can fix atmospheric nitrogen, reducing the need for synthetic nitrogen fertilizers. Green manure crops are grown and incorporated into the soil to enhance organic matter and nutrient content.

Incorporating Livestock:

Livestock can contribute to nutrient recycling. Manure and urine can be used as organic fertilizers, enriching the soil with nutrients.



Crop Residue Management:

Crop residues, when left in the field or properly managed, can return nutrients to the soil and improve its structure.

Precision Agriculture:

Utilizing technology, like GPS-guided equipment and remote sensing, can optimize nutrient application, taking into account variations in soil and crop conditions across the field.

Cover Crops:

Cover crops, such as legumes or grasses, can be grown during fallow periods to protect the soil, improve soil health, and fix nitrogen.

Water Management:

Efficient irrigation practices help ensure that nutrients are effectively taken up by the crop, reducing losses due to leaching and runoff.

Farmer Training and Education:

Educating farmers about the principles of INM and providing training on its implementation is crucial for its success.

Environmental Considerations:

INM emphasizes reducing nutrient runoff, leaching, and environmental pollution, promoting sustainable agricultural practices. Integrated Nutrient Management is a holistic approach that aims to maximize nutrient use efficiency, enhance crop productivity, and promote sustainable farming practices, taking into account both economic and environmental considerations. The relative contribution of each component to INM for a farming system depends mainly on their local availability and socio-economic factors. The major components of INM are fertilizer, organic manures (FYM, green manures, crop residue, by products like pressmud, distillery effluents etc.) and bio-fertilizers.

Sugarcane being a long duration and exhaustive crop with C₄ metabolism, demands large amounts of moisture, nutrients and sunlight for its optimum productivity. It has been estimated that an average crop of sugarcane yielding 100 t of cane/ha removes 208, 53, 280, 30, 3.4, 1.2, 0.6 and 0.2 kg N, P, K, S, Fe, Mn and Cu respectively from the soil (Singh and Yadav, 1996). Despite the fact that sugarcane is bestowed with the most efficient C₄ photosynthetic metabolism, sufficient sunlight, soil moisture near to field capacity and adequate plant nutrient supply are prerequisite for optimal sugarcane production. Fertilizer to be considered most important component of INM and fertilizers play a significant role in sugarcane production by providing essential nutrients that are necessary for plant growth, development, and the accumulation of sugar. To achieve yield benefits, it is important for sugarcane growers to follow recommended fertilizer application practices, including soil testing, nutrient balancing, and proper timing of applications. These practices should be tailored to the specific nutrient needs of sugarcane at various growth stages and regional soil conditions. Proper management can help maximize the contribution of fertilizers to sugarcane production while minimizing environmental impacts. Indian soils are mostly deficient in available nitrogen (N). The application of N ranges from 200 to 400 kg ha⁻¹ in tropics and 120-150 kg ha⁻¹ in sub tropics (Tayade et al., 2022). Hardly, 30-40% of the applied fertilizer nutrient is utilized by the sugarcane and the rest is lost through the various pathways like leaching, surface run off, volatilization, denitrification, soil erosion and fixation in soil (Thorburn et al., 2017). Thus efforts are required to increase the fertilizer use efficiency. The present scenario of yield stagnation and low fertilizer use efficiency in sugarcane warrants the judicious use of nutrient by integrating organic and inorganic nutrient sources. Phosphorus and potassium not only



improve cane productivity but also sugar recovery by providing resistance against biotic and abiotic stresses and improve synthesis and storage of sugar. Their judicious use improves the response to nitrogen and other costly inputs. However, escalating prices of phosphatic and potassic fertilizers are major bottleneck in achieving balanced fertilization and necessitate their efficient utilization.

The concept of integrated nutrient management proposes the inclusion of legume and other crops in cropping systems together with the combined use of chemical fertilizers, organic manure, crop residue, and biofertilizers. Application compared to using artificial fertilizer, using compost at the time of planting increased the cane output. Due to fertilizer application over no fertilizer, a quantum leap in terms of cane yield gain by several folds was seen. Green manuring, or planting legumes before sugarcane, is another crucial element of INM that has been useful in raising sugarcane yield. It is important to highlight that using simply organic and chemical fertilizers was insufficient to maintain sugarcane soil production, emphasizing the prudent and balanced integration of these nutrient sources. According to Mathew and Varughese (2007), the application of pressmud at a rate of 5 tonnes/ha in conjunction with the necessary NPK fertilizer doses significantly improved the availability of nutrients. According to Tayade et al. (2019), IPNS+STCR modules-based nutrient management in plant and ratoon crops resulted in increased cane output and an improvement in soil fertility. In order to increase sugarcane productivity and profitability, it was found to be beneficial to combine the use of biofertilizers with FYM (10 t ha⁻¹) + STCR 150-based fertilizers (390 kg N ha⁻¹ and 94 kg P ha⁻¹), while in ratoon crops, fertilizer scheduling @ 20 t ha⁻¹ FYM + STCR 150 (390 kg N ha⁻¹, 94 kg P ha⁻¹, and 117 kg K ha⁻¹) was recommended.

Sugarcane Dry Biomass (Trash)

Sugarcane trash, which includes the leaves, tops, and other plant residues left in the field after sugarcane harvesting, contains various nutrients and organic matter. It is expected that 15 t/ha of dry cane garbage will degrade over a year to create 2.5 t of organic matter (Calcino et al. 2000). The nutrient composition of sugarcane trash can vary depending on factors such as the sugarcane variety, soil conditions, climate, and crop management practices. According to Shrivastava et al. (1992), cane garbage typically comprises 68% organic matter, 0.42% N, 0.15% P, 0.57% K, 0.48% Ca, and 0.12% Mg, in addition to 25.7, 2045, 236.4, and 16.8 ppm Zn, Fe, Mn, and Ca, respectively. As a result, it can be integrated with other INM components in sugarcane successfully. Generally, the nutrient composition of sugarcane trash is as follows:

Table 2: Nutrient composition on dry leaves (Trash) of sugarcane

Nitrogen (N)	1.0% to 1.5%	Calcium (Ca):	0.2% to 0.4%.
Phosphorus (P)	0.05% to 0.20%.	Magnesium (Mg)	0.1% to 0.2%.
Potassium (K):	0.2% to 0.6%	Sulfur (S):	0.05% to 0.15%.

Nitrogen is an essential nutrient for plant growth and is important for the development of the sugarcane crop. Phosphorus is crucial for root development and overall plant growth. Potassium is essential for many physiological processes in plants, including sugar accumulation. Calcium is important for cell wall structure and root development. Magnesium is a component of chlorophyll and plays a role in photosynthesis. Sulfur is important for amino acid and protein synthesis. Micronutrients: Sugarcane trash can contain various micronutrients, including iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), and boron (B), though their concentrations are relatively low. Sugarcane trash is rich in carbon content due to its organic matter. The carbon-to-nitrogen (C:N) ratio is a crucial factor in the decomposition of sugarcane trash and its impact on soil organic matter. Sugarcane trash is a significant source of organic matter, which is essential for



improving soil structure, water-holding capacity, and microbial activity. It's important to note that the nutrient composition of sugarcane trash can change over time as it decomposes in the field. As the trash breaks down, nutrients are gradually released into the soil, providing a slow-release nutrient source for subsequent crops. Utilizing sugarcane trash in the field, either by incorporating it into the soil or leaving it as mulch, helps recycle these nutrients, enriches the soil, and promotes sustainable agriculture. Sugarcane trash, which includes the leaves, tops, and other plant residues left in the field after sugarcane harvesting, holds significant value and serves various purposes in agriculture and beyond. Sugarcane trash holds immense significance in agriculture and sustainable land management. It offers a range of benefits, including soil enrichment, erosion control, nutrient recycling, carbon sequestration, and the potential for biomass energy production. To fully realize these benefits, it is crucial for sugarcane growers to adopt responsible and sustainable practices for managing sugarcane trash in the field. Its significance lies in its multiple applications and benefits (Figure 1):

- Sugarcane trash, when left on the field or incorporated into the soil, acts as a valuable source of organic matter. It improves soil structure, water-holding capacity, and aeration, contributing to overall soil health.
- Sugarcane trash contains essential nutrients that are returned to the soil as it decomposes. This nutrient recycling reduces the need for synthetic fertilizers and helps maintain soil fertility.
- The presence of sugarcane trash on the soil surface acts as a protective mulch, reducing soil erosion caused by wind and water. This helps preserve topsoil and prevent nutrient loss through runoff.
- Sugarcane trash, when maintained on the field, helps suppress weed growth by acting as natural mulch. This reduces the competition for resources between weeds and the sugarcane crop.
- The mulching effect of sugarcane trash helps retain soil moisture, reducing water evaporation from the soil surface. This can be particularly beneficial in regions with limited water resources.
- The trash layer provides insulation to the soil, moderating temperature fluctuations. This can be beneficial for crop growth by protecting it from extreme temperatures.
- As sugarcane trash decomposes, it sequesters carbon in the soil, contributing to efforts to reduce greenhouse gas emissions and mitigate climate change.
- Sugarcane trash can be used as a source of biomass energy through processes like combustion or biogas production. It can serve as a renewable energy resource, reducing the carbon footprint of energy production.
- Sugarcane trash can be utilized as animal feed or bedding for livestock. The fibrous content of the trash makes it suitable for cattle and other livestock species.
- Some parts of sugarcane trash can be used for making biodegradable materials, such as paper and packaging products. This contributes to sustainability and environmental conservation.
- By making use of sugarcane trash, farmers can reduce the cost of synthetic fertilizers, improve crop yield, and potentially generate additional income by selling excess biomass or utilizing it for various purposes.
- Utilizing sugarcane trash in agriculture reduces the need for burning, a common but environmentally detrimental practice in sugarcane farming, which generates air pollution and harms soil health.

Wastes from Sugar Mills: Current Potential

The Indian economy places a high priority on some industries, like the sugar business. Pressmud,



bagasse, molasses, sugar mill waste water, wasted wash, and fly ash are just a few examples of the numerous by-products of the sugar industry that must be continuously disposed of and handled with care in an environmentally sustainable manner. Vinasse or spent wash, which has a very high BOD value, a strong odor, a dark hue, and a chemical makeup, is the most dangerous effluent that distilleries create. As a result, it significantly pollutes the soil and water eco-system. Therefore, these effluents need to be continuously monitored and treated before being disposed of in open areas. Other solid and liquid wastes generated during the crushing, clarifying, and crystallization processes are nutrient and cellulose rich, and they might be used profitably to satisfy various societal demands and raise the financial standing of the sugar processing facilities. However, their inclusion in agricultural systems has been steadily growing, mostly as a source of organic manure, a mulching material, or a soil-improving agent to increase soil fertility and production. Research shows that sugar mill wastes have a huge potential to increase cane output under various agro-climatic situations across the nation. According to Kumar, (2003) and Uppal, (2004) every 100 tons of sugarcane crushed on an average gives 10 t of pressmud. One ton of molasses can produce around 225 L of alcohol. The sugar industry generates about 7.5 million t of molasses, 45 million t of bagasse, 5 million t of pressmud and 40 million m³ of spent wash.

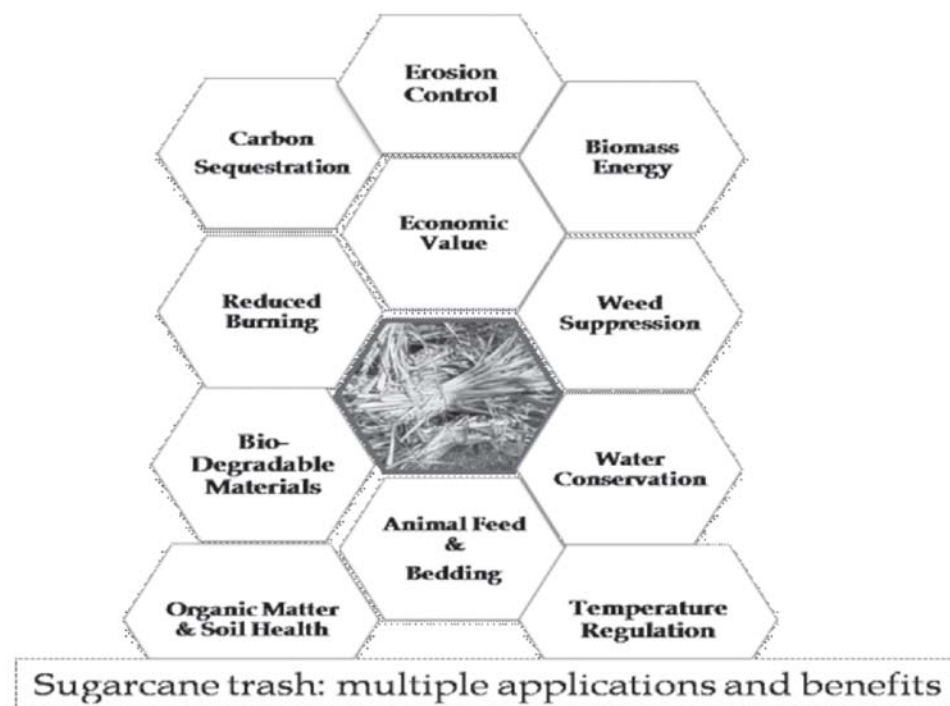


Figure 1: Significance of sugarcane trash on soil and environment

Pressmud

Pressmud is soft, spongy, amorphous and dark brown to brownish white solid material containing fibre, sugar, coagulated colloids including cane wax albuminoids, inorganic salts and soil particles. The composition varies depending upon the quality of canes crushed and the process followed for the clarification of cane juice in a sugar factory (Mishra et al., 2022). It is one of the best sources of organic matter having good nutritional value. Pressmud, also known as press mud or filter cake, is a byproduct of the sugar industry produced during the sugarcane juice clarification process. This material, rich in organic

matter and nutrients, has the potential to serve as a valuable soil amendment in agriculture. Here are some reasons why pressmud is considered a potential soil amendment:

Pressmud as a potential soil amendment

A. Organic Matter

Pressmud is a rich source of organic matter, which improves soil structure, increases water-holding capacity, and promotes microbial activity. The organic material in pressmud helps enhance soil health.

B. Nutrient Content :

Pressmud contains essential plant nutrients, including nitrogen (N), phosphorus (P), and potassium (K). These nutrients are released slowly as the pressmud decomposes, providing a long-term nutrient source for crops.

C. pH Regulation:

Pressmud can help buffer soil pH, making it more stable. This can be particularly beneficial in soils with pH imbalances.

D. Microbial Activity

The organic matter in pressmud supports the growth and activity of beneficial soil microorganisms. These microorganisms aid in nutrient cycling, decomposition of organic material, and overall soil health.

E. Nutrient Retention

Pressmud can enhance the soil's ability to retain nutrients, reducing the risk of nutrient leaching into groundwater and improving nutrient availability to plants

F. Soil Erosion Control:

The use of pressmud as a soil amendment can help reduce soil erosion by improving soil structure and preventing surface runoff.

G. Fertility Improvement:

Over time, the incorporation of pressmud into the soil can increase soil fertility, leading to improved crop yields and quality.

H. Sustainable Agriculture

Using pressmud as a soil amendment aligns with principles of sustainable agriculture by recycling a byproduct, reducing the need for synthetic fertilizers, and improving soil health

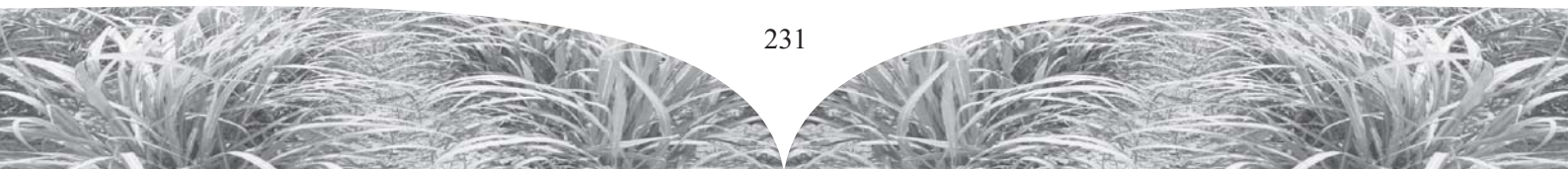
I. Waste Utilization:

Utilizing pressmud diverts a waste product from landfills and contributes to more environmentally responsible waste management practices.

J. Beneficial for Certain Crops

Pressmud can be particularly beneficial for certain crops and in specific agricultural systems. It may be more advantageous in regions where it is readily available from the sugar industry

The effluents from the sugar industry, after being treated with the activated sludge method, contain substantially fewer pollutants than required and might very well be used to irrigate sugarcane fields. The sugarcane transformation process is highly complex, generating significant amounts of wastewater comprising liquid and solid discharges from the processing, handling, and transformation of sugarcane (Moussa et al., 2023). According to several field studies on the impact of treated sugar mill waste water on



sugarcane crops, irrigation with the waste water had no negative effects on the crops' output (Hasaan et al., 2021). Crude spent wash has negative impacts on sugarcane crops and soil characteristics. Jain and Shrivastava (2012) also found that high doses of spent wash had an inhibitory effect on stress-induced enzyme activities. This effect may be caused by the spent wash's high toxic metal content. According to Saini et al. (2010), sugarcane may be irrigated safely with wasted wash at a 20 percent concentration (1:5 dilution), and this practice has been shown to increase sugarcane crop growth and output over time. Pressmud composting is crucial in reducing the negative effects of used wash and sugar mill waste water (Figure 2).

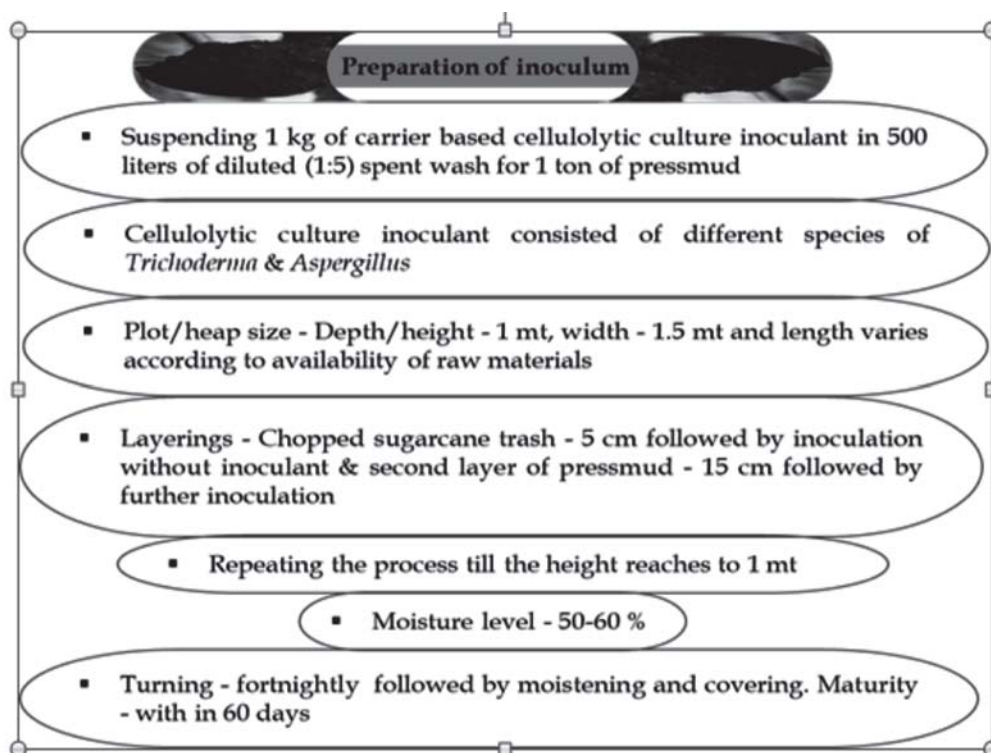


Figure 2: Pressmud Composting Technique with Spent Wash and Sugar Mill Waste Water

Bio-fertilizer

The long-term goal of sustainable agriculture is to remove obstacles that prevent agricultural production systems from being socially acceptable, economically viable, and environmentally sound. Since they are environmentally beneficial and serve as an alternative to chemical fertilizers, bio-fertilizers assume significant relevance in this perspective. Bio-fertilizers are soil enliveners that generally contain microorganisms that can fix nitrogen and mobilize phosphorus in a sustainable way (Figure 3). Since they don't function like chemical fertilizers, the moniker is misleading. They are physiologically active substances that aid in enhancing plant nutrition, promoting plant development, and quickening the breakdown of plant leftovers. A lot of nitrogen is added to sugarcane by non-symbiotic soil bacteria like *Azotobacter*, *Azospirillum*, and *Acetobacter*, which are frequently utilized as bio-fertilizers (Thanakkam et al., 2023). Additionally, Phosphobacteria and certain fungi aid in the Solubilization and assimilation of soil phosphorus by sugarcane plants. The cane yield and sugar production were found to be improved by the use of bio fertilizer @ 10 kg Azospirillum or Gluconactobacter and Phosphobacteria @ 10 kg per hectare. Generally speaking, bio fertilizers are sprayed 45 and 90 days after sugarcane is planted. By biologically fixing atmospheric nitrogen and improving native P availability to the crops, the use of bio fertilizer lowered

the amount of chemical fertilizer used to sugarcane. Hari and Srinivasan (2005) provide evidence of the differences between the various microorganisms and their divergent behavior with different sugarcane cultivars. Studies done on farmer fields also shown that applying 75% recommended dose of nitrogen along with *Azospirillum* or *Gluconactobacter* improved the cane production. Compared to *Gluconactobacter* and *Azotobacter*, *Azospirillum* increased the cane and sugar output.

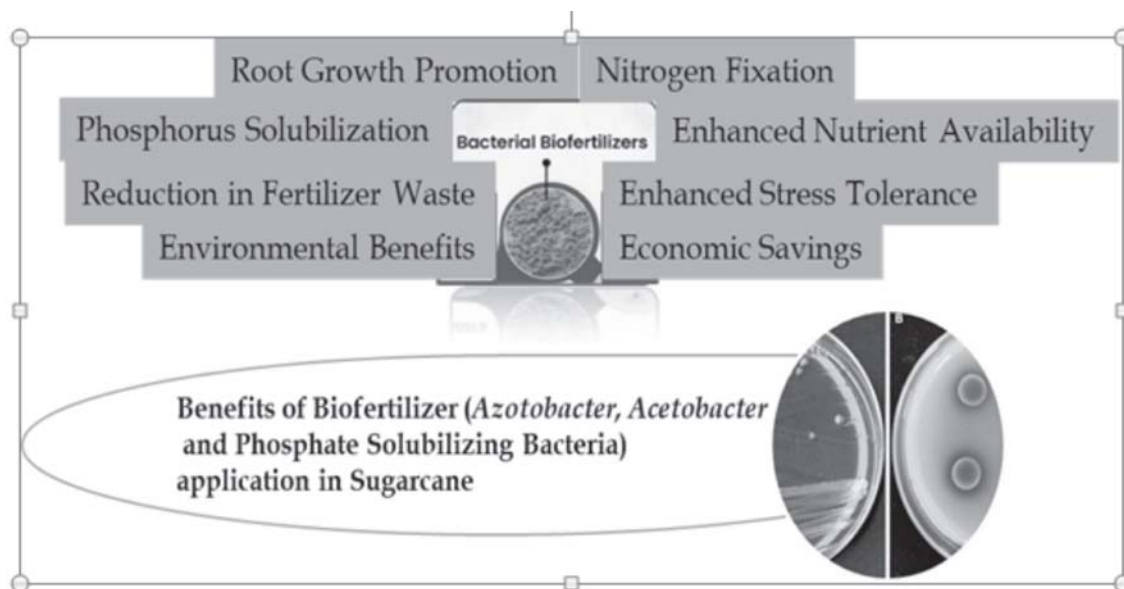


Figure 3: Bacterial bio fertilizers role in nutrient use efficiency in sugarcane cultivation

Conclusion

Integrated Nutrient Management advocates combining the use of chemical fertilizers, organic manure, crop residue, and bio fertilizers, as well as using legume and other crops in cropping systems. With an overall improvement in the quality of the resource base, INM holds considerable potential for addressing the rising nutrient needs of intensive sugarcane production and maintaining productivity at greater levels. To maintain high levels of productivity, efforts should be made to use manufacturing wastes, crop residues, and bio fertilizers together. Additionally, agro-ecology specific integrated nutrient management packages should be created for various sugarcane farming scenarios. A sound fertilizer management program should be implemented to increase fertilizer use efficiency and lower fertilizer costs.

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