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Integrated Nutrient Management (INM) in Maize for Enhanced Soil Fertility and Yield

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Integrated Nutrient Management (INM) has emerged as a crucial agronomic method for sustaining maize yield and soil health. Maize (Zea mays L.), a nutrient-intensive crop, needs a balanced supply of macro- and micronutrients throughout its growth stages. The goals of INM are to maximize nutrient availability, lower input costs, and improve soil biological activity through the use of organic materials (like FYM and vermicompost), inorganic nutrients (like NPK), and biofertilizers (like Azospirillum and phosphate-solubilizing genes). This combined strategy improves cation exchange capacity and promotes a slow accumulation of soil organic carbon, which improves nutrient retention. INM is a climate-smart strategy for sustainable intensification of maize production systems because it helps to maintain soil health while fulfilling the high nutrient requirements of maize. Long-term soil fertility and ecosystem resilience are enhanced by INM, which also promotes beneficial microbial populations and biodiversity in the rhizosphere. Research has demonstrated that INM greatly lowers nitrate leaching and aids in carbon sequestration, both of which are essential for mitigating the effects of climate change.

Keywords: INM, Maize, Nutrient, Biofertilizers, Azospirillum.

Introduction

In India, maize and wheat have gained a lot of popularity as cereal crops. The control of nutrients has a major impact on grain output. Maize is referred to be the "Queen of Cereals" and the Miracle Crop worldwide because of its superior genetic yield potential compared to other cereals. In India, 8.69 million hectares of maize are grown, yielding 21.81 million tonnes of grain with a productivity of 2509 kg ha-11. The primary crop of Himachal Pradesh is maize. The yield of maize, which was grown on 0.30 million hectares of land, was 0.67 million tons, with a productivity of 2270 kg ha-11. India ranks second in the world for wheat production, with an area of 30.2 million hectares, 93.5 million tonnes of production, and 3093 kg ha-11 of productivity, making wheat a significant post-monsoon crop for the nation. In Himachal Pradesh, wheat, together with other grains, takes up the most land—roughly 0.35 million hectares—and produces 0.68 million tons annually, with a productivity of 1968 kg ha-11. The most common farming system in the State of Himachal Pradesh is maize (Zea mays L.) and wheat (Triticum aestivum L.), which are both members of the Poaceae family and account for almost 85% of the state's total food grain production. In addition to having reduced cropping intensity since the fields are left fallow for almost three months, the current cropping system's productivity in small and marginal farmers' fields is extremely low. As a significant nutrient for plant nourishment, nitrogen is essential to the growth system of plants. It is a crucial component of the proteins, enzymes, and nucleic acids that produce chlorophyll, and in the end, the nitrogen that plants receive is crucial for all crops. In addition to providing N, P, and K, organic sources convert inaccessible sources of bound phosphorus,

micronutrients, degraded plant residues, and elemental nitrogen into forms that plants can absorb. However, long-term soil quality and crop productivity can be increased by combining the use of chemical fertilizers with different organic sources. Vermicompost, natural minerals, and microbes are all combined to create the enhanced vermicompost. Because chemical fertilizers are expensive and have fewer residual effects, they cannot cover the needs of crops and cropping systems alone. For this reason, the use of organic manure is becoming more and more popular. As a crucial component of soil that affects the physical, chemical, and biological characteristics of the soil, the addition of organic matter—whether in the form of crop residues or yard manure, vermicompost, or compost—is essential for maintaining soil fertility and supplying plant nutrients. The addition of organic manure either increases the soil's microbial activity or affects the enzymatic activity of the soil due to its composition of the additional materials.

Concepts of Integrated Nutrient Management

A technique called integrated nutrient management (INM) aids in maintaining agricultural output and safeguarding the environment for future generations. It can be characterized as the implementation of soil fertility management techniques that optimize the use of organic resources and fertilizers to improve agricultural yields. This approach involves the prudent application of suitable chemical fertilizers and organic resources. To increase crop yield, stop soil deterioration, and enhance soil-water infiltration, it blends both organic and inorganic nutrient sources, contributing to the future food supply. Growing agricultural yield and environmental sustainability must be balanced for there to be sustainable food security. This balance cannot be threatened by either nutrient excesses or deficiencies.

According to the FAO, the three primary elements of INM are as follows:

- Balancing fertilizers or mixing organic and inorganic fertilizers to maintain or increase soil fertility.
- Enhancing plant nutrient reserves in soils
- Reducing environmental losses by improving the effectiveness of plant nutrients

Therefore, by combining the advantages of all potential plant nutrient sources, INM seeks to maintain or modify soil fertility and feed plant nutrients to an ideal level for maintaining crop yield. By increasing food production and quality and boosting soil fertility, integrated nutrient management is now thought to be a strategy that helps smallholder farmers address several problems, including poverty and food insecurity.

Effect of Chemical Fertilizer on Maize Production

Chemical fertilizer is a substance that is added to the soil to supply one or more necessary components for the development and yield of plants. The three main elements are nitrogen, potassium, and phosphorus; the subsidiary elements include magnesium, calcium, sulfur, and other elements, including boron, manganese, iron, zinc, copper, and molybdenum. The mineral components that are removed from the soil through grazing, erosion, leaching, or harvesting are replaced by fertilizers, which increase soil fertility. The best method for reducing soil nutrient depletion is to use chemical fertilizers, which provide high N and P contents that the crop can easily absorb and improve farmers' livelihoods. This is because the nutrients found in chemical fertilizers are instantly available for plant absorption. Crop yield rose when proper fertilizers were applied, improving nutrient concentrations in plant tissue. When compared to the original value, the application of prescribed 100% NPK fertilizers significantly improved the available P, K, and total N and boosted crop output, indicating a major contribution to maintaining the health of the soil. Although chemical fertilizers can be used sparingly to boost agricultural yields, Africa has not adopted them very well. Despite input subsidies and credit systems, efforts to bring chemical fertilizer technology to smallholder farmers in Africa have not been extremely effective. Excessive use of chemical fertilizers, particularly N fertilizer, can destroy aquatic and atmospheric ecosystems and cause harmful changes in food. Inorganic sources of nutrients initially increased output, but over time, they resulted in unsustainable productivity (Mahajan et al. & Satya Narayana et

al.). When chemical fertilizer is used for continuous cropping, it causes an imbalance of nutrients in the soil, leaching of nitrogen, contamination of water supplies, eradication of beneficial insects and microorganisms, crop susceptibility to disease outbreaks, soil acidification or alkalization, or decreased soil fertility, all of which result in irreversible harm to the entire system. This is because when misapplied or over what the plant requires, they are prone to losses in gaseous forms or by leaching. Interest in using organic fertilizer as a source of nutrients has increased due to the drawbacks of inorganic fertilizers and their high price.

Effect of Organic Fertilizer on Maize Production

The organic materials used in agriculture as recycled or external inputs to produce crops for both commercial and subsistence purposes are known as organic fertilizers or organic sources. The most viable organic sources include animal manure, crop wastes, compost, green manure, relay or intercropping of legumes (dual-purpose legumes), and biomass from short- to long-term fallows. Due to their socioeconomic constraints, smallholder farmers are unable to use chemical fertilizers properly; hence, these sources have been identified as alternate nutrient sources for their soils.

The mineralization-immobilization process, microbial energy sources, precursors to soil organic matter, nutrient addition, and decreased P fixation in the soil are some of the ways that organic manures impact nutrient availability. In addition to improving the major and minor organic nutrients and the general physical properties of the soil, organic manure also promotes soil aeration, stops leaching losses, and reduces physical compaction of the soil. The entire spectrum of nutrients is incorporated into the soil in a comparatively short amount of time by the combined action of the nutrient components in organic fertilizer, and their benefits persist longer for the current crop. The biological and physicochemical qualities of the soil have decreased as a result of agriculture devoid of organic manure or crop leftovers. Two distinct kinds of organic fertilizers increased maize grain yields by 70% compared to yields obtained with chemical fertilizers. This outcome suggests well for the region's future growth in organic cereal crop output. The expansion and progression of maize crops highlighted the potential for enhancing maize production and productivity in the Daloa region through the use of poultry manure (PM).

Effect of Integrated Nutrient Management on Maize Production

A suitable and balanced application of both organic and inorganic fertilizers could result in a high and consistent yield. Numerous studies demonstrated that INM greatly increased maize production and yield characteristics. The performance of maize and nutrient availability was improved more when chemical fertilizer and poultry manure were applied together than when either fertilizer was applied alone. The greater yields from applying poultry manure and chemical fertilizer together as opposed to applying poultry manure and control alone; yet, the yield from applying both organic and inorganic fertilizer together did not differ substantially from that from applying only inorganic fertilizer. Increased maize production, plant height, 1000 grain weight, and LAI when 20 tons ha−1 FYM and 60 kg·N·ha−1 inorganic fertilizer were applied together as opposed to when each fertilizer was applied separately. The use of less artificial fertilizer and more organic manure in tandem for sustainable crop production. Because the nutrients in the goat and poultry manures are released more quickly than in FYM, the application of these manures resulted in more rapid development.

Effect of Integrated Nutrient Management on Nutrient Uptake of Maize

Integrated nitrogen Management (INM) profoundly affects nitrogen absorption in maize by augmenting nutrient accessibility, expanding soil vitality, and fostering microbial activity The combination of organic manures (such FYM and vermicompost), inorganic fertilizers (RDF), and biofertilizers (like Azospirillum and phosphate-solubilizing bacteria) is very beneficial to maize, a crop that requires a lot of nutrients. Throughout the crop growth period, a balanced supply of macro- and micronutrients will be provided by this integrated strategy. Better root

development and more effective nutrient absorption are made possible by organic inputs, which additionally improve soil structure, retained water, and microbial biomass. Biofertilizers improve the processes of nutrient fixation and solubilization, particularly for phosphorus and nitrogen. When compared to the application of chemical fertilizers alone, research indicates that INM treatments frequently lead to noticeably better intake of nitrogen (N), phosphorus (P), and potassium (K). Additionally, the rhizosphere's enhanced microbe activity and organic acid synthesis promote the absorption of micronutrients, including zinc (Zn) and iron (Fe). Therefore, INM promotes sustainable maize farming, long-term soil fertility, and increased crop production and nutrient uptake.

Economic Importance of Integrated Nutrient Management

Sustainable crop production depends on maintaining the fertility of the soil at the economically optimal level with a suitable cropping strategy and a cheap fertilizer rate. The inherent potential of Integrated Nutrient Management methods to preserve and enhance soil fertility and health results in longer-term crop production and less crop output unpredictability.produced sustainable agriculture, constant output, and higher income. Prior studies show the economic significance of integrated nutrient management.

When organic and chemical fertilizers were applied together, the price of fertilizer was lower than when either fertilizer was applied alone, according to economic research by Jinwei and Lianren. In agriculture, Integrated Nutrient Management (INM) is economically significant, especially when it comes to improving crop production systems' sustainability and profitability. INM lessens the need for costlier chemical inputs through the combination of chemical fertilizers, biofertilizers, and organic manures, which ultimately decreases production costs. The frequency and amount of fertilizer treatments required are decreased when using organic sources, which also increases the fertility of the soil and nutrient-use efficiency. Biofertilizers reduce the cost of synthetic inputs by increasing the availability of nutrients, particularly nitrogen and phosphorus. Furthermore, INM techniques provide a balanced nutrient supply, which raises crop yields and quality and increases farmers' earnings from the market. Because of its contribution to environmental sustainability, INM may be able to command higher pricing in the market due to its growing value in ecological labeling and organic certification programs. As a result, INM guarantees farmers' long-term financial stability while simultaneously optimizing input use for higher yields.

Conclusion

In developing countries, the most significant physiological cause of low crop production is the decline of soil fertility. It is crucial to apply inorganic fertilizers to preserve soil fertility. In the production of maize, Integrated Nutrient Management (INM) is a comprehensive and sustainable method that successfully raises crop yield and soil fertility. Through the synergistic combination of chemical fertilizers, biofertilizers, and organic manures, INM ensures a steady and balanced supply of nutrients across the crop growth cycle. In a cropping system, the application of organic manure can preserve organic matter in the soil, give the current crop balanced nutrients, and leave a large amount of residual nutrients for the crops that come after. Crop yield and soil organic matter both benefit from the retention of crop leftovers on farms. Adoption of INM over time minimizes environmental degradation, lowers input costs, and reduces reliance on chemical-based fertilizers. Therefore, INM becomes a feasible option for sustainable maize cultivation, guaranteeing increased agricultural systems' ecological stability, economic profitability, and productivity.

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