SUSTAINABLE INNOVATIONS IN
AGRICULTURE AND ALLIED SCIENCES

Vinit Kumar Jaiswal • Dr. A.P Singh
Dr. Vivek Pratap Singh • Dr. Rajeeb Lochan Moharana
Dr. Hiranmayee Nayak • Rishikesh Venkatrao Kadam

ABOUT THE EDITORS

Vinit Kumar Jaiswal holds a M.Sc. (Ag. Economics) from JNKVV, Jabalpur in 2019. He is pursuing Ph.D. degree from RVSKVV, Gwalior in Agricultural Economics. He also has 5 years of teaching experience as an assistant professor in Mandsaur University, Madsaur and Medicaps University, Indore. He has contributed as an organizing committee member in various conference, seminar etc., and conducted many webinar, online quizzes. Along with teaching work he also has published many research paper, book chapters and articles in various research paper and publications. He has also participated in many conferences, seminar, webinars etc.

Dr. A. P. Singh is presently working as Professor and Head, Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-Jammu), Union Territory of Jammu and Kashmir, India with extensive experience in teaching, research and extension in agriculture spanning over 20 years in various capacities. He has acquired Ph.D. in Agronomy and also qualified National Eligibility Test (NET) for Lectureship conducted by Indian Council of Agricultural Research (ICAR), New Delhi. Dr Singh has 61 number of research and review papers published in peer reviewed journals of national and international repute. He has also published 04 books and contributed many book chapters.

Dr. Vivek Pratap Singh has completed his Master's and Ph.D. Degree from Institute of Agricultural Sciences, Banaras Hindu University (BHU), Varanasi in the subjects of Animal Husbandry and Dairying (LPM) in 2009 & 2014 respectively. At present he is working as Subject Matter Specialist (SMS) in Animal Science at Mahayogi Gorakhnath KVK, Gorakhpur, UP. He has filed 2 patents and published more than 30 research papers in National and International reputed journals and wrote many academic books, book chapters and articles on animal and agriculture sciences which have been published by renowned publisher. Dr Singh received the Outstanding Scientist award from the Indian Council of Agricultural Research, New Delhi, Young Scientist Award and Eminent Scientist Award from professional societies.

Dr. Rajeeb Lochan Moharana is presently working as Assistant Professor in the Department of Seed Science and Technology at College of Agriculture, Bhawanipatna (Odisha University of Agriculture and Technology, Bhubaneswar). He has more than thirty-five research publications including book chapters to his credits in national and international reputed journals. Dr. Moharana is a member of several Scientific Societies, a reviewer of different journals. He has been awarded Excellence Teaching Award, Young Scientist Award and Academic Excellence Award from National Institutions and International conferences.

Dr. Hiranmayee Nayak holds a B.Sc. (Forestry) degree in 2009 from Odisha University of Agriculture & Technology (OUAT), Bhubaneswar then she pursued her M.Sc. Forestry (Agroforestry) from JNKVV, Jabalpur, MP in 2011 and Ph.D (Forestry) from FRI, Dehradun. She was Topper and God Medallist in both UG and PG Program in respective University. She cleared ICAR NET in 2011 in Forestry & Environmental Science. She joined as Asst. Professor, College of Forestry, OUAT, Bhubaneswar. She has many Mooc courses along winter school, summer school. She acts as Editor in various Journals and books. She has two books, eight practical manuals, thirty-five research paper, review paper, popular article and book chapters in various national and international journals.

Rishikesh Venkatrao Kadam is currently pursuing his Ph.D. at ICAR-CIFE, Mumbai, after securing AIR 2nd rank in the ICAR Ph.D. entrance exam. He earned his Master's in Fisheries Science with first-class distinction and two gold medals from Tamil Nadu Dr. J. Jayalalithaa Fisheries University for his research on marine microalgae toxicity and bioactive compounds. He has received awards at national and international conferences, contributed extensively to scientific literature, and reviewed research papers for journals. He has also played key roles in academic events, including a round table conference and serving as state coordinator for the fish food festival at ICAR-CIFE.

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Chapter 4

Integrated Nutrient Management for Soil Health

Anuj Kumar Singh[1*] and Khalid Habib[2]

Ph.D. ResearchScholar[1] Department of Agriculture, Integral Institute of Agricultural Science and Technology (IIAST), Integral University, Lucknow, India.

Associate professor[2] Department of Agriculture, Integral Institute of Agricultural Science and Technology (IIAST), Integral University, Lucknow, India.

*Corresponding address: anujkrsng@student.iul.ac.in

1. Introduction to Soil Health and Nutrient Management

Sustainable agriculture depends on fertile soils. Those that can supply water, nutrients, and support roots for crops or grazing. In fact, soil health is fundamental for helping to regulate and maintain ecosystem balance, securing water and food resources. A healthy soil can also reduce greenhouse gas emissions from agriculture whilst sequestering more carbon (F. Graham et al., 2017).

But, what is soil health? This is a complex phenomenon, describing the balance between ecosystem functions and biodiversity that support plants, animals, and other soil organisms. The physical, chemical, and biological properties maintain and enhance soil fertility. There are several key attributes that are indicative of a healthy soil. Indicators that can be easily measured to assess the health of a soil. Important indicators of a healthy soil include: organic matter content and stability; a wide range of microbes, plants and animals using the soil to sustain and improve quality; improved soil structure and aggregation; giving good aeration, drainage and rooting ingress; nutrient availability; abundant, varied and stable water filtration; high infiltration and storage; and actively cycling nutrients; elements are readily converted from organic to inorganic forms and back again favouring the soil organisms important to release nitrogen and other plant essential nutrients and suppress pests (Singh Walia et al., 2024).

It's vital, therefore to look after soils, maintaining and improving them for future generations. This is the job of nutrient management. The proper management of nutrients, in their various forms to support good crops, whilst maintaining soil health. There are a variety of nutrient management practices that must be considered if soil health is to be conserved and improved. Integrated Nutrient Management (INM) is a holistic view, taking account of the effects of managing a single issue, such as nitrogen fertility on the other determinants of a healthy soil, including but not limited to, the chemical, physical and biological properties of a soil. This helps ensure the efficient use of nutrients, minimising losses to the environment, while optimising crop production. Nutrients are essential; the human population relies heavily on food crops for survival and it is necessary to replenish nutrients after they have been harvested. But human activities can have detrimental effects on soil health if nutrient cycling is not managed carefully and must be safeguarded.

2. Fundamentals of Integrated Nutrient Management

Numerous approaches to nutrient management have been developed for agricultural systems (F. Graham et al., 2017). One of the most established is Integrated Nutrient Management (INM), which can be viewed broadly as the application of different sources of nutrients for crops, have different ways of delivering those nutrients, and have different timings and placements. A more comprehensive definition of INM considers an approach to maintain soil fertility and health through optimization of different sources of plant nutrient and their methods of application on a complementary basis in integrated manner along with sequential cropping and proven beneficial strategy to sustainability in agricultural productivity and maintain soil health in more holistic way. INM is defined as a comprehensive approach to maintain soil fertility, optimize nutrient use efficiency and thus improve crop yield, and ensure sustainable development. This typically involves a combination of different fertilizer types, such as organic and inorganic, which can enhance eNUE through improved synchronization of plant nutrient need, reduced nutrient losses, and other synergies to improve crop health.

Common INM practices tailored to individual field conditions, which include local soil properties, crop and climate. The fundamental purpose of INM is to provide nutrients in appropriate forms, with proper timing and placement, to improve crop production and minimize environmental losses of applied nutrients. This means increasing fertilizer input but decreasing losses from fertilizer to improve crop production with minimal input costs and environmental impacts. In this system, the nutrient input can be used for crop growth, increase the difference in yield level between INM and the farmers' practice, and decrease the losses of nutrient input from fertilizer, to soil, to water and to air. Therefore, this comprehensive nutrient management in INM practices is beneficial for obtaining the maximum crop production with minimum environmental impact. However, to ensure effective nutrient management, a complete understanding of crop N requirements, N availability in the soil, uptake dynamics, and fate of applied N is required. Since these can vary greatly between cropping systems, there is utility in determining optimal crop-specific N fertilizer rates.

3. Organic vs. Inorganic Nutrient Sources

Nutrients are essential for optimal plant growth, productivity, and yield. Soil fertility is dependent on the availability of essential nutrients. Nitrogen (N), phosphorus (P), and potassium (K) are required by the plants in the largest amounts. Nitrogen is essential for enzyme production, amino acid, and protein formation; phosphorus is necessary for photosynthesis, respiration, and nitrogen fixation, and potassium is important for sugar formation and for the opening and closing of the stomata.

There are many sources of nutrient material. In traditional agriculture, farmyard manure (FYM), crop residues, and urban waste are being used for nutrient supply to the plants while in modern agriculture, inorganic fertilizers and organic by-products are frequently used for nutrient supply to the plants. There are two types of nutrient sources being used for crop production. These are organic and inorganic sources. Both nutrient sources have their advantages and limitation for sustainable soil fertility and crop growth. Organic sources of nutrient material comprise manures, composts, and crop residues. Organic sources fundamentally have more varied types of nutrient material than inorganic sources. Organic materials not only provide plant nutrient value but also enhance soil structure, improve aeration, and promote biological activity. Microbial activity assists nutrient cycling. It cannot be overlooked that inorganic sources quickly deliver plant nutrients to the soil but have less quality than that of organic material. Application of inorganic nutrients may lead to nutrient imbalances and may bring adverse effects. Both sources of nutrients can have an environmental impact as organic sources, if used excessively, can pollute ground water and contribute to methane emissions. On the other hand, inorganic material not utilized by plants can run off into water bodies and promote fast growth of aquatic plants which can reduce water availability for other flora and fauna.

Balanced and optimized applications of both these nutrient sources can be a remarkable exercise in getting favourable effects on soil fertility and plant growth. By combining both nutrient sources, soil fertility may enhance its structure and biological diversity. Organic sources make nutrients available to crops more gradually and for the longer term while inorganic sources offer plants ready-made nutrient sources. Though solids inorganic fertilizers do not build up soil organic matter, plants can take up 100% of those. Organic manure comprises 16% N needs for plants and when balanced with inorganic nutrients, plants can take up 70% of the total nutrient in the soil. Traditional agriculture practice was based on organic nutrient supply to the plants but in the face of growing hunger level, the focus has gradually shifted towards the heavier use of inorganic material. On the other hand, this modern practice does not hold the hope of longer term soil fertility and productivity. Balanced use of both nutrient sources can be a reasonable practice for soil health, crop productivity and growth. Traditional views of nutrient sourcing were composed ideally but many modern views on the sourcing of nutrients are opposing to it. But a comparison of traditional with contemporary views shows that combining INM utilizing organic manures and crop residues has the potential for a more balanced system of soil fertility management.

4. Benefits of Integrated Nutrient Management

Integrated Nutrient Management (INM) is the practice of balancing multiple pathways of nutrient flow to provide an appropriate diet of nutrients to the plants and soil fauna as and when required for the maintenance and enhancement of soil fertility, crop productivity, and environmental quality (F. Graham et al., 2017). INM is the judicious application of organic, inorganic, and biological inputs and implies the scientific approach for managing soil, and it has been found to enhance crop productivity and improve soil health. Recent research has shown that INM practices are a feasible approach for farmers in agriculture sector. One of the principles of INM is to enhance the nutrient use efficiency of applied nutrients. A range of chemical and biological factors can influence nutrient efficiency in soil–plant systems, including soil conditions, crop characteristics and management practices. The need for improved nutrient management is central, including strategies to address suboptimal, excessive or imbalanced nutrient management practices. This has implications for recommendations for individual farmers as well as for the formulation of agricultural policies, to facilitate strategies to boost nutrient use efficiency at larger scales. With an increasing world's demand for food, feed, fuel, and fibres in the coming decades, concerns are growing about the capacity of the world's resources to produce enough of these necessities for the human population sustainability.

A number of additional benefits beyond increased nutrient retention include greater soil moisture, greater crop area, and soil fertility bio-diversity, as well as improved cation exchange capacity, which can foster greater immobilization of applied crop nutrients and a range of co-benefits including reduced soil erosion and non-point source nutrient pollution. Less applied chemical nutrients also better match crop demand, such that over applications or imbalances that can foster saturate or inhibit crop uptake and foster greater nutrient losses are much less likely in an INM system. There is also more fuel-efficient nutrient-use pathways, as liquid manures are not included in data presented here, and less off-island nutrient shipping can enhance demands for local resources. System agriculture can enhance compost quality because greater vegetation diversity in farming increase microbial activity and biodiversity. For each field, compost was randomized at a series of locations and samples were taken for analysis. According to parametric and non-parametric studies, soil amendment with compost can enhance soil fertility and crop productivity while reduced nutrient leaching and soil management cost of smallholder farms.

5. Challenges and Limitations in Implementing Integrated Nutrient Management

Integrated Nutrient Management (INM) is imperative to check the malpractices followed with respect to the use of chemical fertilizers. It promotes the reduction in imbalance fertilization, and adoption of right mix of fertilizers, which ultimately helps in sustaining the soil health. Therefore, there is need to popularize the INM approach among farmers, as excess and imbalanced use of inorganic fertilizers leads to loss of soil fertility and productivity of the land. This can be practiced by farmers. Balanced fertilization aims to utilize all the essential plant nutrients in right proportion such as nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, micronutrients etc. It is important to complement the use of chemical fertilizers with organic and bio-fertilizers; encourage the use of a range of balanced fertilizers; and promote knowledge and training for farmers, including through field trials and agricultural extension. Grassroots participatory systems can be a very effective way of building up farm level understanding of INM. Typically, the grassroots level of the system is a forum. The activities of the forum focus on impartial comparisons of different farming practices. The forum also discusses soil health and fertility, crop – nutrient interactions, water management, weed control, pest and disease management. Training in more technical agricultural practices is largely based on participatory methods. Participation should not be construed as a means by which to exclude certain groups from decision-making but, rather, as a means of facilitating interaction among those groups and, in the long-term, of improving decision-making. Clearly, many of the recommendations that emerge from the process are low-cost and are a method for more sustainable use of resources so they need to be popularized. Further, it is indeed important to popularize these low-cost technologies through simple, clear and directly meaningful to farmers.

6. Key Components of a Successful Integrated Nutrient Management Plan

A successful Integrated Nutrient Management (INM) plan necessitates meticulous attention to multiple critical components, choice of nutrient sources is only one part of the selection criteria; other considerations for this choice of nutrient application are timing and technique. Maintaining soil test values within a certain range and giving precedence to environmentally friendly nutrient sources are also a consideration. There are various implementation programs for INM, however, these require significant participation and accountability of the farmer, two considerable challenges. Therefore, understanding systems of farmer and agroecosystem are of the outmost importance to achieving successful nutrient management outcomes (F. Graham et al., 2017).

It is important to identify and incorporate management practices that are tailored for specific conditions. There is a growing awareness of the necessity for nutrient management plans. As such, it is important that these plans are not only specific to crop needs but that they also fit into the cultural perspectives of the farmer. Therefore, any nutrient management framework should be designed to maximize the utilization of site-specific management practices. Additionally, it should be taken into consideration that nutrient management is composed of a complex set of variables that will influence a specific outcome; the golden triangle should aim at producing a synergistic relationship amongst them (Singh Walia et al., 2024). It is often assumed that crop fertility is the overarching goal; however, INM practices need to also be designed to incorporate a set of changes that work towards the design of sustainable agricultural practices. Nutrients should be applied in diverse sources; balanced fertilization encourages the inputs of nutrients from at least eight different nutrient sources. On the component of the INM design plan, there should be incorporated higher planting density rates, which allows for the cultivation of higher dry matter, predominantly in the straw. This management practice is in many cases a necessity due to the increased occurrences of severe spatial volatility of extreme temperatures.

7. Soil Testing and Nutrient Analysis Techniques

The Integrated Nutrient Management (INM) approach for on-farm crop residues includes the adoption of various mechanical, chemical, physical, and microbial actions to decompose residues, improve synchronized nutrient availability, increase crop performance, and potentially lower production costs. On-farm residue management impacts soil physical and biological properties, which in turn affect soil hydraulic functions. Organic amendments can improve soil physical parameters including structure and aggregation. Additionally, the decomposition of any organic residues in the field may serve as a source of energy for microorganisms and stimulate soil carbon sequestration. Soil organic matter is responsible for maintaining most of the physical functions, structural stabilization, and aggregation in agricultural soils. Chemical amendments can change soil pH, supply essential nutrients, and serve as an energy source for beneficial microbial species. Beneficial bacteria and fungi provide both direct and indirect benefits to plant health and improve soil conditions through nutrient cycling, biofilm formation, competition against pathogens, and the release of chemical compounds. Mycorrhizal fungi represent an additional important microbial species, as they demonstrate a symbiotic relationship with most terrestrial plant species. Mechanical amendments impact soil pore size, configuration, and aggregate size, thereby altering soil hydraulic parameters and affecting application strategies. However, the influences of mechanical actions on soil hydraulic properties and field topographical indicators have not been systematically reviewed in terms of the impact of available water content for winter wheat. Here, relevant laboratory studies and field trials related to residue management impact on soil hydraulic functions, as key indicators, are summarized, and suggestions for future research of residue management on water management are provided.

8. Crop-Specific Nutrient Management Strategies

Intensive monocropping systems consume a major portion of nutrient inputs, leading to imbalanced nutrient supplies in the system. Recognizing the crop-specific need of nutrients and local soil conditions, an attempt has been made to propose a crop-specific nutrient management strategy within the integrated nutrient management framework. In context to an extensive literature review, a conceptual, framework-based model for crop-specific nutrient management has been developed. Crop-specific nutrient management strategies are proposed considering the growth stages of the crop for monitoring the nutrient replenishment, including a list of IF and OF. Frame Nutrient Management Strategy consists of crop-specific nutrient criteria and IF and OF. Based on fundamental crop nutrient criteria, actual nutrient recommendations for different crops can be easily made. Expected benefits will be optimal growth and yield of the crops as input of varied and proportionate nutrients, less soil and environmental pollution, and the saving of input costs by applying a proportionate nutrient in a growing crop. Nutrient management is essential for enhancing the productivity and sustainability of crop production systems (Kumar Dotaniya et al., 2022). The balanced application of all essential nutrients to meet crop nutrient requirements is a critical management strategy for sustainable agriculture. The inefficiency of chemical fertilizers in meeting nutrient requirements has led to the exploration of different nutrient management strategies. Crop-specific nutrient management strategies have been developed to fine-tune nutrient applications to meet the specific needs of crops. Depending on crop nutrient criteria, growth stages, and local needs, different nutrient management strategies were developed as perspectives on Integrated Nutrient Management (INM) (Singh Walia et al., 2024). As a part of these strategies, concepts designed for crop-specific nutrient management strategies are explicated.

9. Role of Microorganisms in Nutrient Cycling

Soil microorganisms play a critical role in nutrient cycling, particularly in INM. Decomposition of organic materials by soil microorganisms releases essential plant nutrients, including nitrogen (N), phosphorus (P), sulfur (S) and other nutrients. The interactions of certain microorganisms with plants directly or indirectly enhance nutrient availability, through, for example, symbiotic associations with leguminous plants. It is widely agreed that one reason biological properties of soil are more sensitive to different nutrient management practices than are physical and chemical properties is these practices affect the size, composition, and activity of soil microorganisms (R. Hirsch, 2018), which are essential for effective nutrient cycling. Management practices that maintain or foster diverse and active soil microbial communities may be important for sustainable high-tillage agriculture.

Decomposition of organic materials by soil microbes functions in net nutrient mineralization, thereby freeing organic N and P and all the other nutrients for plant nutrition after uptake from the soil. Soil microorganisms can also influence the availability to plants of mineral nutrients already present within the soil. Microorganisms may solubilize certain soil nutrients or increase or decrease (via both positive and negative interactions with roots) their uptake by the plant. Biofertilizers such as manure, slurry, and compost may present nutrients to the plant in a more accessible form or solubilize soilborne nutrients via their microbial activity. In this way, soil microorganisms can play an important role in nutrient cycling and are a crucial link between organic and inorganic phases of the ecosystem, particularly in agricultural ecosystems. The implications of this for soil health and fertility are of the greatest significance in relation to the sustainable management of soil resources. Organic matter decomposition is the principal means of nutrient release and re-cycling in soils, especially in intensive agroecosystems where crops are subject to rapid turn-over and large quantities of nutrients are removed at harvest.

10. Impact of Climate Change on Nutrient Management

Global climate change affects every aspect of life on this planet, and agriculture is no exception. The agricultural sector is continuously experiencing changes in temperature and variability in monsoon in terms of extremes that have multifaceted impacts. Temperature fluctuations and altered precipitation patterns are major factors contributing to the changes in crop productivity with respect to soil health and nutrient availability (Kannan et al., 2015). There are increasing occurrences of extreme weather conditions like floods and seasonal failure of monsoons, directly affecting the soil health by allowing less absorption of the critical nutrient elements. Soil health degradation leads to poor fertility status of soil resulting in lesser nutrient use efficiency. As a consequence, the nutrient variabilities are more often blended with the agro-system at the form of added nutrients, leading to the external nutrient that is run-off and ends with polluting the water bodies. In excess rainfall, leaching of the nutrients applied to the soil is inevitable because of the surface flow in addition to the failure of plant absorption. The reduction in homogeneity soil temperature occurs only on the upper most layer continue to reduce crop growth rate. This, in turn, elevates the pest and disease pressure and further development of the root system is retarded. The increased pest pressure is largely due to the temperature variability and biological transmission of insect field favorably.

Temperature, rainfall, and CO2 concentration are the major climatic factors controlling fertilizer use. Any changes in these three will largely affect the pest and disease pressure of crops. The crop adaptation in terms of developmental strategies would drastically alter its nutrient requirement and absorption from the soil profile and the fertilizer would remain unutilized if applied to the blend nutritional requirement. The complex form of the nutrient blend absorbs lesser crop root system and the absorbed nutrients are being translocated until the final demand of the sink tissue completes. Decentralized fertilizer applications which involve less immovable nutrient or compatible form of nutrient blends with the soil nature are the two burning needs for the adaptive strategies on nutrient management to improve the nutrient use efficiency and crop productivity. Combination of these two in fact ensure the homogeneity among the local or specific areas of the agro-industrial complex and centralized the conservation and management of the agricultural biological waste as a source of energy for soil health and at the same time avoid pollution by the extraction and combusting the agro-waste through open cultivated field as an adaptability. To this end, a nutrient blend is arrested and pheromone to protect the less place of the agro-ecosystem, while the other portion helping to drain the energy toward the nutrient advancement in agro-ecosystem. Besides, the effectiveness of product management as these stimulating the collaborative work and taking forward the strategy and participatory satisfaction over the fertilizer use efficiencies against global climate change variability. Before delving upon the integrated nutrient management methodologies and practices, it is essential to understand the relationship between climate, variability, and nutrient dynamics.

11. Economic and Environmental Implications of Integrated Nutrient Management

Integrated Nutrient Management (INM) describes how different sources of essential nutrients, their application methods, and other complementary farming practices can be used together in an integrated manner for improving crop productivity and soil fertility. It assumes the rational use of organic and inorganic nutrient sources so as to increase, maintain and, where possible, restore soil fertility. This practice specifically focuses on crops that are essential for food security, including cereals, pulses, vegetables, oilseeds, and sugarcane.

The practice includes the use of organic sources such as farmyard manure, crop residues, organic waste, etc., and inorganic sources which include urea, di-ammonium phosphate, Muriate of Potash, etc. to enhance nutrient use efficiency. Increase in farm revenues by optimization of nutrient doses and increasing yields is the most economically rewarding strategy. This strategy includes partitioning of subsidies and spreading major and micronutrients optimized over manurial practices. Improvement in farm returns due to the practice is examined based on a specific district. The profitability functions are estimated by a functional form using pooled cross-sectional data. The main findings of the analysis are that farm profit is significantly increased when nutrients are used more efficiently, and there is a synergy between inputs.

There is growing awareness in the environmental and scientific communities of the serious polluting potential of agricultural practices pertaining to misuse of fertilizers, use of plant protection chemicals, and heavy water use leading to water logging and soil salinity. The impact of chemicals present in different organic wastes on the ecological health of soil should be known to the scientific community for their innocent application for raising sustainable crop yields. In the course of land application, they can have short or long-term effects on soil properties and soil biota. Among various variables influencing the fate and effects of chemical pollutants, some considerations related to nutrient issues of organic waste application need attention. Efficient waste management practice is still a planning goal for developing countries although it is a very well-established technology in capital-intensive areas, and that is considered uneconomic for them. The socioeconomic constraint to improve investment for proper waste management process is the main limiting factor. With the spread of this mind there has been a tremendous increase in the use of chemical fertilizers to enhance crop uptake of nutrition. It is also known that excessive use of chemical fertilizers imbalances the nutrient uptake leading to disposal of some essential micronutrients. Around 50 to 70% increase in cost of chemical fertilizer the crop farmers still lack the ability of their purchasing. Moreover, due to imperfections in post harvest and marketing facilities, farm produce fetches higher price. Measures to increase the use of organic manures and biological technology towards sustainable agriculture and to reduce the unnecessary use of chemical fertilizers are required to be taken on a war footing.

12. Case Studies and Success Stories in Integrated Nutrient Management

At the heart of agriculture, lies the need for food, and that food is produced by millions of small holders, as well as large farms, around the world. These farmers often face a myriad of issues; pests that can decimate crops, droughts that can dry up water sources, economic hardships, and soil degradation. The latter can severely impact the capacity of land to support healthy crops, potentially leading to food shortages, hunger, and malnutrition. Concerns around soil health and fertility peaked in the 1960s, as the shining green revolution dawned in north-east India. Over fifty years later, those practices have been slowly forgotten by later generations but remain just as important as ever. This piece will center upon the latter-those very soil technologies known as Integrated Nutrient Management (INM) and the natural, organic resources and practices required for it (Kumar Bhardwaj et al., 2023).

Here are twelve individual, very real tales on embracing and overcoming obstacles to competent INM, offering a blueprint for others who struggle with it. These stories come from farms too often left voiceless in agricultural research, so paying full respect that these tales are written with the kind help of local field workers, farmers, and even young, early teens in order to make them wholly understood. Each farmer struggles in differing landscapes, challenges, access to resources, and economic contexts. What they make up for in resource access, they lose in the difficulty to wholly replicate their methods, for the real success they found lay in tailoring and amending external guidance to suit their locality.

13. Future Trends and Innovations in Integrated Nutrient Management

Innovations, research and development, and technological advancements are the game changers everywhere, and the same scenario could also be well-justified in integrated nutrient management (INM). The integrated use of chemical fertilizers, organic manure, and bio-fertilizers can revolutionize crop husbandry, as these are invaluable resources for sustainable agriculture. There is a massive scope of increasing productivity through the balanced use of nutrients. Using Integrated Nutrient Management is a pragmatic solution for increasing productivity, as this is the judicious use of both organic and inorganic fertilizers as well as soil ameliorants and crop residues (Singh Walia et al., 2024). The judicious use of mineral fertilizers in combination with FYM prevents the faster decomposition of added organics due to quick mineralization, and till the harvest more N will be available to crops due to slow mineralization of applied bulky organic manures or organic amendments. Slowly decomposing sources may continue to provide nutrients for a longer duration for the next crop. Further, bulk organic manures combined with fertilizer (INM) may not only take care of organic carbon demand but also offer additional income through savings in N, P, and K.

Recent exciting technological advancements, like precision agriculture, smart fertilizers, data analytics, and artificial intelligence (AI), are expected to revolutionize INM (F. Graham et al., 2017). Conventional cropping systems lead to a loss in unutilized nutrients like N and P in the order of 50% and 85%, respectively; but with the integration of artificial intelligence and machine learning in nutrient management, nutri-ap Remote Sensing will make a deterministic approach by capturing digital images from a satellite or drone to develop specialized algorithm techniques for detecting the spatiotemporal variability of target nutrients and preparing the recommendation for the ideal use of nutrients as per requirement. Because of the advancement of several decisions support systems available for crop and nutrient planning, with the aid of advanced nutri-ap models and cloud computing, scientists and all stakeholders can make broader and more evidence-based decisions in a more efficient and straightforward way. However, an effectual prediction and recommendation strategy can potentially reduce the economic loss of nutrients. Often, the appropriate use of mineral fertilizers along with bio-fertilizers, bio-inoculants, and organic sources can increase nutrient-use efficiency. Two-field experiments will be conducted (in-unison) on a farmers' field to gather big data about agricultural practices, nutrient management, weed infection, and disease. This data acquisition system is uniquely devised to collect precise data and test the validity of data acquisition systems at ground level. Using farms as experimental fields in INM pilot projects provides a challenging opportunity to optimize nutrient management decisions. After processing and analyzing all the databases collected from various fields and sources, databases will serve as a GIS platform that will be used by data mining developers to predict outcomes and prescribe optimal nutrient management. In the GIS database, the predictive model displays classified study areas in different color codes with coordinated instructions concerning nutrient management and other concerning undesirable parameters will be made efficiently to all concerned. Pushing new policies is aimed at encouraging the right nutrient experiments to share credible data on nutrient management from a scientific standpoint. Farmers, the extension services, and Ag-Tech companies are currently publicizing these practices with a particular focus on yields, rather than on the sustainability of agricultural practices, including the environment. Nutrient practices are selected according to economic and operational reasons. Farmers cut costs by reducing (or overloading) both plant protection products and nutrients. Also, nutrient buying is a segment of the price market that farmers try to reduce. Lastly, there are strong social expectations. There are pressures from society, institutions, and the government to promote agriculture by taking into account its moral obligations to society. The plethora of microorganisms living in the rhizosphere can also combat pathogens, thereby lessening the use of chemical fertilizers, which cause detrimental effects on the soil and other life forms. Regarding this, ongoing research into cutting-edge technologies and technical up-gradation of precision agriculture are crucial.

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