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Current Trends in Plant Nutrition and Fertilizers

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Abstract**:** *Plant nutrition practices have been the main endeavor of mankind since the beginning of agriculture to increase crop productivity. Plant nutrition practices, traditionally based on the application of organic fertilizers and partially unprocessed minerals until the last century, have evolved into the widespread use of chemicals after the second half of the last century and have responded significantly to the food needs of the rapidly growing world population during this period. It is known that agricultural emissions have an important share in environmental pollution in the environmental awareness that increased after 1970s all over the world. In addition, it is the common consensus of agricultural scientists that plant nutrition based only on chemical fertilizers causes a decrease in plant productivity with deterioration in soil quality and health. Today, new organic and mineral fertilizers, fertilizer combinations, plant nutrition products, soil-improving chemical and microbiological preparations and plant nutrition management practices developed to feed plants are successful and promising.*

Keywords: *Plant nutrition, Fertilizers, Soil fertility*

1. Introduction

Throughout history, the success in feeding humanity and combating diseases caused by malnutrition has been made possible by farmers' continuous improvement of agricultural practices under changing conditions. Plant nutrition practices have formed an important part of the process of food production, which is a basic requirement for humanity. The evolution of these practices throughout history has played an important role in the development of societies and the transformation of agriculture. Since time immemorial, plant nutrition has aroused human curiosity, attracted great interest among philosophers and researchers, and it was thought that the problem of low food production in agriculture was due to poor plant nutrition. Efforts to increase productivity in agricultural production and alleviate hunger were successful only after the discovery of the nutritional needs of plants in the mid-1800s. In the 1880s, various mineral fertilizers were developed to increase plant nutrients in low fertility soils and this practice has been widely adopted worldwide since 1950 [1].

Today, it is understood that the nutrient requirements of plants produced under conventional agricultural techniques cannot be met only with widely used mineral fertilizers. Yield losses in agriculture over the last 40-50 years, increasing environmental pollution and related public health problems have brought the sustainability of agricultural practices into question. Due to the deterioration of soil quality and health and production losses, a logical combination of mineral fertilizers used in plant nutrition with organic and biological nutrient sources has been promoted for sustainable production. Nowadays, approaches and strategies in plant nutrition practices are determined on the one hand by the necessity of developing fertilization technologies that will enable agricultural production in challenging natural and soil conditions due to the increasing human demand for food, and on the other hand by the pressure of increasing environmental problems related to agricultural practices.

1.1. Plant Nutrition Practices in History

The first people, who lived by gathering plants from their natural environment and hunting, started to settle down and become agricultural communities with the neolithic revolution and started agricultural culture and plant nutrition practices developed together. The first agricultural communities realized that plants feed on soil and that the soil's power to grow plants could be exhausted over time. Ancient communities practiced

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fertilization practices in order to increase the healthy growth of plants and the fertility of the soil. During this period, various composts and animal droppings were one of the early plant nutrition methods used to improve soil fertility and traditionally practiced to this day. In addition, various organic and inorganic materials such as organic wastes, river and pond silt, guano, green manure, ash, bone, lime and gypsum have also been used for soil fertilization and improvement. In medieval Europe, the development of agriculture and the feudal land system increased the importance of fertilization. At the beginning of the 16th and 17th centuries, plant nutrition science began to evolve from natural philosophy to chemically based experimental science. In the late 19th and early 20th centuries, the discovery of chemical fertilizers accelerated the transformation of agriculture. The German chemist Justus von Liebig identified the essential nutrients needed for plant growth and this knowledge led to the development of synthetic fertilizers. The discovery of chemical fertilizers to increase productivity has radically changed plant nutrition practices ever since. In the 20th century, one of the major developments was the industrial-scale production of ammonia from atmospheric nitrogen. The resulting ammonia became the main fertilizer intermediate in the rapidly developing fertilizer industry [2]. The intensive use of chemicals in agricultural production and increased agricultural production was described as the Green Revolution in the 1960s [3]. Today, chemical fertilizers are undoubtedly still an important driver of productivity. However, it has become evident that plant nutrition practices based solely on chemicals are not sustainable, with negative changes such as declining soil health and fertility, deterioration in crop yield quality, environmental pollution, and loss of biodiversity [4].

1.2. Current Plant Nutrition Practices

Today, unbalanced preferential nitrogen application, inadequate P and K application, and lack of secondary macro and micronutrient application in the fertilization of agricultural soils potentially jeopardize healthy soil and environmental resources for future generations and our sustainable food security goals [5]. Regional and crop-based general fertilizer recommendations, which have been in place for many years in many countries, have largely lost their relevance today.

Today, new cultivated plants, new varieties and hybrid seeds, classical, semi-dwarf and dwarf cultivation practices in fruit growing, and species and varieties grown specifically for consumer demands have led to a high and wide range of nutrient requirements in terms of quantity and timing. Fertilization programs need to be adjusted according to the nutritional requirements of newly developed hybrid varieties. However, the limited number of studies on the nutritional requirements of new varieties is one of the most important problems in making accurate fertilization recommendations. In this regard, sharing experiences with the producers who have analyzed the genetic potential of the plant can be a good guide in solving the problems.

On the other hand, a large number of agrochemicals and fertilizers have been developed in the agricultural sector in various forms, in compound combinations with varying ratios and in new compositions. Their complexity has shown the need for the development of new analysis evaluation criteria with sophisticated, comprehensive and product-specific approaches instead of fertilizer and fertilization recommendations made with the conventional, classical approaches so far. It is important that agricultural analysis laboratories are also active in the recommendations on the form, dosing, application and timing of these chemicals and fertilizers, and that fertilizer industry-laboratory relations are integrated. Following the developments in the fertilizer and other agricultural chemicals sector and developing recommendations based on soil analysis in the use of preparations with different mechanisms of action and complex composition in fertilization recommendations will enable more effective use and adoption of these new preparations [6].

Today, due to the high dependence of advanced plant species and varieties on chemical fertilizers, the basic plant nutrients such as nitrogen and phosphorus have been disconnected from their natural cycle. It is estimated that the total phosphate reserves in the world for fertilizer production may be sufficient for only 50 to 100 years for food production [7]. Unless new reserves are discovered and innovations are developed in the recovery of phosphates from wastes, it is inevitable that the costs of crop production will increase. Recycling nitrogen and phosphorus from agricultural wastes, increasing the efficiency of fertilizer applications and using organic fertilizers are important elements of sustainable agriculture. Recycling of nutrients is easier in agricultural enterprises where plant and animal production are carried out together. Therefore, comprehensive mixed crop-animal production systems, especially in developing countries, can significantly contribute to future agricultural sustainability and global food security [6].

1.3. Nano Fertilizers

Nano-sized materials have great potential in many application areas because they have small size and large surface area and differ especially in their chemical reactivity. Nano fertilizers are synthesized or modified forms of conventional fertilizers to improve soil fertility, nutrient use efficiency and quality of agricultural products. Nano fertilizers have nanometer-sized particles and high solubility and have been developed to meet the nutritional needs of plants more efficiently. Nutrient uptake resulting from the smaller surface area of nanomaterials enhances nutrient surface interaction. Some nano-fertilizers are able to preserve nutrients in capsules, making them more resistant to environmental factors and providing nutrients to plants in a slow-acting manner over a longer period of time. These properties allow nutrients to be taken up more effectively by plants. However, while nanofertilizers are promising in plant nutrition applications, more research is needed on product safety and environmental impacts of this new technology [8].

1.4. Liquid Fertilizers

Liquid fertilizers are fertilizers that provide essential nutrients to plants in dissolved form in liquid. These fertilizers are mixed with water and applied to plants through irrigation. The main components of liquid fertilizers are macronutrients such as nitrogen, phosphorus, and potassium. They may also contain micronutrients and trace elements. In addition, liquid organic fertilizers produced from agricultural residues and industrial wastes are becoming increasingly popular [9]. The easy absorption of liquid fertilizers by plants, customizability according to the growth stage and needs of plants, faster response to nutritional needs, less waste, ease of storage and application provide important advantages in plant nutrition. Liquid fertilizers, a special class of fertilizers among different fertilizers, show strong promise in hydroponics, hydroponics, aeroponics and soilless protected cultivation, and even in open fields for perennial fruit crops. As a component of modern agriculture, liquid fertilizers have been very successfully applied in fertigation practices to adapt nutrient use during critical growth stages of plants. When combined with high-tech irrigation systems and fertilization equipment, liquid fertilizers can optimize plant nutrition processes, increasing productivity and contributing to more efficient use of natural resources. This innovative approach is considered an important tool to move the agricultural sector towards a more efficient, environmentally friendly and food-secure future and is seen as part of sustainable agricultural practices.

1.5. Bio Fertilizers

Biofertilizers consist of organic materials derived from living organisms or biological processes. Microorganism cultures such as rhizobium, azotobacter, acetobacter and phosphate, potassium and zinc solubilizing bacteria, mycorrhizal biofertilizers and carrier-based consortia are included in the scope of microbial fertilizers. Such fertilizers are used to provide nutrients to plants, improve soil fertility and provide positive effects on soil microbiology. Biofertilizers can be used instead of or in combination with conventional chemical fertilizers. However, the use of biofertilizers requires careful planning according to soil type and plant species.

Currently, organic fertilization-based plant nutrition requires the application of very large quantities of organic fertilizers to meet the nutrient needs of cultivated plants, which increases production costs. Biofertilizers are considered advantageous because they are applied in small quantities, have low costs, reduce the need for chemical fertilizers, and provide multifaceted synergistic benefits in maintaining soil health and suppressing plant diseases [10]. Biofertilizers are nowadays an important part of sustainable agricultural practices and seem promising in maintaining the long-term health of soils.

1.6. Organomineral Fertilizers

Organomineral fertilizers are a special type of fertilizer obtained by mixing organic materials (vegetable and animal wastes, animal droppings, compost, etc.) with mineral fertilizers, providing both mineral and organic nutrients to plants [11]. Organomineral fertilizers synthesized by combining these components both increase the amount of useful nutrients and enrich the amount of organic matter in the soil. In this way, they play an important role in improving soil quality and health with their rich mineral nutrient and humic substance contents, long-term beneficial effects and positive effects on soil physical properties. Organomineral fertilizers have the advantage of providing both fast and long-lasting effects. While delivering mineral components to plants quickly, organic matter decomposes slowly, soil microbial activity increases, providing long-term nutrient supply to plants and ensuring continuous and balanced nutrition of plants. In addition to increasing productivity, these fertilizers promote sustainable agriculture by minimizing the environmental impact of chemicals.

1.7. Site-Specific Nutrient Management

Site-specific nutrient management is an approach that aims to provide the nutrients needed by plants in the most effective way by optimizing fertilizer and irrigation applications in agricultural fields [12]. The 4R nutrient management principles of applying the right source of plant nutrients at the right rate, at the right time and in the right way form the basis of the precision nutrient management approach. Site-specific nutrient management customizes plant nutrition practices based on the specific requirements of an area or field segment. This approach aims to identify the nutrient needs of each field segment using soil and plant analyses and advanced data analytics. Site-specific nutrient management could effectively replace general fertilizer nutrient recommendations in the future to achieve high nutrient use efficiency, economic profitability and a lower environmental footprint.

1.8. Plant Biofortification

Micronutrient deficiencies in soil limit crop productivity and the nutritional quality of food, which in turn affects nutrition and human health. This can lead to growth problems, weak immune systems and mental development problems, especially in children. Plant biofortification is an important agricultural strategy used to increase the nutrient content of plants to promote healthy diets and combat nutrient deficiencies. Plant biofortification is defined as procedures aimed at increasing the content of certain elements, nutrient compounds and vitamins in plant yields in order to improve their biological quality and consequently improve the health of food consumers [13]. Agronomic biofortification is achieved through the application of micronutrient fertilizers such as iodine, zinc, molybdenum, selenium to the soil and/or foliar application directly to the leaves of the crop. Biofortification of different crop varieties offers a sustainable and long-term solution to provide people with micronutrient-rich crops.

1.9. Maintaining Soil Health and Integrated Nutrient Management

Soil health is the basic of productive and sustainable agriculture. Healthy soils provide essential nutrients for plant growth and nutrition. Organic farming practices, polyculture, cover crops and the return of organic wastes to the soil help to maintain soil health. Organic fertilizers consist of materials of various organic origins, ranging from the waste material of various plant or animal crops, animal excreta and agro-industrial waste products. These materials contain all the nutrients that plants can absorb from the soil, albeit in limited quantities. Organic matter plays a vital role in increasing soil biological activity and improving its physical properties. However, due to their low nutrient content and slow nutrient release rates, organic fertilizers alone are insufficient to meet the nutrient requirements of high-yielding crops. Today, the increasing demand for chemical fertilizers in crop production and the ever-increasing costs associated with declining soil fertility necessitate the integrated use of organic and inorganic nutrient sources for sustainable crop production and better soil health. Integrated nutrient management means maintaining optimum soil fertility and plant nutrient supply to sustain desired productivity through integrated optimization of benefits from all possible sources of organic, inorganic and biological components. Therefore, the integrated use of chemical, organic and biological sources of plant nutrients and their different management practices have significant potential not only in maintaining agricultural productivity and soil health, but also in reducing the need for chemical fertilizers [14].

1.10. Soil and Leaf Tests for Effective Fertilization

The main objective of plant nutrition is to increase productivity and net gain through effective fertilization management. In order to achieve this goal, the nutritional power of the soil must first be accurately determined. In conventional soil fertility tests, some basic soil properties and some available nutrients are analyzed and fertilization recommendations are made for plants. In fertilization recommendations based on soil analysis, the amount, form and application time and way of fertilizers containing the nutrients required by the plant can be determined. Leaf analysis of the plants clearly shows the nutritional status of the plant during the relevant vegetation period and the necessary nutrient applications made in this period can provide the maximum product to be obtained in the production season. In plant nutrition management, soil analyses and plant analyses are evaluated integrally in a production season, and the fertilization program applied at the beginning of vegetation can be revised during the growing period depending on the conditions. In the effective management of the plant nutrition program, timely consultation of the findings of soil and plant analyses and crop observations and taking preventions facilitates the solution of plant nutrition problems [6].

2. Conclusion

Over the last 70 years, major advances in the fertilizer industry and plant nutrition products have led to significant increases in crop production efficiency and have helped to meet the growing food demand of a world population that has almost tripled. In addition, advances in experimental sciences and analytical techniques have played an important role in solving soil fertility and plant nutrition problems. Despite these advances in agriculture, plant nutrition practices based solely on chemical fertilizers over the last century have led to deterioration in soil quality and health, depletion of natural resources, environmental pollution and public health problems, and are projected to cause a potential food security crisis in the future. Under the pressure of these problems, alternative techniques and products for sustainable plant nutrition management have been introduced and some of them are very promising. Success in plant nutrition technologies will be achieved through an effective plant nutrition management that can rapidly respond to the needs of the cultivated plant in its life cycle, protect soil quality and health, and correctly apply analysis-based fertilization practices.

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