Direct RESEARCH JOURNALS
Direct Research Journal of Agriculture and Food Science
Vol. 9 (1), Pp. 7-11, January 2021
ISSN 2354-4147
DOI: https://doi.org/10.26765/DRJAFS23284767
Article Number: DRJAFS23284767

https://directresearchpublisher.org/drjafs/

Review Paper

Review on the role of soil macronutrient (NPK) on the improvement and yield and quality of agronomic crops

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Received 2 December 2020; Accepted 11 January, 2021

ABSTRACT: Primary macronutrients play a very important role in improving the yield and quality of crops. Three main elements are nitrogen, phosphorus, and potassium (N, P, and K) and are required in abundance. They must be readily available through soil medium or fertilizer. Proper plant nutrition is essential for the successful production of agronomic crops. Every macronutrient has its own character and is therefore involved in different metabolic processes of plant life. The present review is an attempt to provide basic information about the role of primary macronutrients in the production and quality of agronomic crops.

Keywords: Macronutrients, yield, quality, agronomic crops

INTRODUCTION

Agronomic crops are cultivated in larger quantities in the world. Since the Green Revolution started, the production of high-yielding cereals (maize, common wheat, and rice), cotton, and sugarcane has significantly increased. Cereals and especially, rice (*Oryza sativa* L.), maize (*Zea mays* L.) and common wheat (*Triticum aestivum* L.) are essential commodities on which human nutrition is based. Expanding population and food demand have required higher production which has been achieved by increasing fertilization, and especially the primary macronutrients. A total of only 16 elements are essential for the growth and full development of green plants according to the criteria laid down by Arnon and Stout (1939).
These criteria are:

(i) A deficiency of an essential nutrient makes it impossible for the plant to complete the vegetative or reproductive stage of its life cycle.

(ii) Such deficiency is specific to the element in question and can be prevented or corrected only by supplying this element.
(iii) The element is involved directly in the nutrition of the plant, quite apart from its possible effects in correcting some unfavorable microbiological or chemical conditions of the soil or other culture medium.

The essentiality of most micronutrients for plants was established between 1922 and 1954. The essentiality of nickel (Ni) was established in 1987 by Brown *et al*., although there is no unanimity among scientists as to whether Ni is essential or beneficial. However, know the time it is added as an essential nutrient. Out of these 17 elements, carbon (C) and oxygen are obtained from the gas CO_2, and hydrogen (H) is obtained from water (H_2O). These three elements are required in large quantities for the production of plant constituents such as cellulose or

starch. The other 13 elements are called mineral nutrients because they are taken up in mineral (inorganic) forms. They are traditionally divided into two groups, macronutrients and micronutrients, according to the amounts required. Regardless of the amount required, physiologically, all of them are equally important. The 13 mineral elements are taken up by plants in specific chemical forms regardless of their source.

Objective

The general objective of this is an attempt to provide basic information about the role of primary macronutrients in the production and quality of agronomic crops.

Specific objective

To describe how nitrogen, phosphorus, and potassium improve cereal crops (rice (*Oryza sativa* L.), maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.), cotton and sugarcane yield and quality.

Literature review

What are primary (macro) nutrients?

Nutrients primary (macro) nutrients are nitrogen, phosphorus, and potassium. They are most frequently required in a crop fertilization program. Moreover, they are needed in the greatest total quantity of plants as fertilizer.

Declining yield growth for major food crops have heightened concerns about agriculture ability to feed a world population expected to exceed 7.5 billion by the year 2020. Decreasing soil fertility has also raised concerns about the sustainability of agricultural production at current levels. Future strategies for increasing agricultural productivity will have to focus on using available nutrient resources more efficiently, effectively, and sustainably than in the past.

In crop production, plants synthesize nutrients in the soil such as nitrogen, phosphorus, and potassium (NPK) from air, sunlight, and water. Without proper management, continuous crop production can reduce nutrient reserves in the soil. As reserves get depleted, crop growth and productivity can be compromised. Over time, cumulative depletion can decrease agricultural production, crop yields, soil fertility and lead to soil degradation. Techniques to conserve and add nutrients to the soil through the application of organic and inorganic fertilizers can help to maintain and increase the nutrient reserves of the soil. Fertilizers replace nutrients removed during harvest and allow growers to manage crop nutrition for maximum yield. Fertilization practices can also have significant impacts on harvested fruit quality and quality retention during packinghouse operations and distribution. These include physiological disorders, disease susceptibility, and compositional and textural changes. Need of nutrients in agronomic crops, Sixteen plant food nutrients are essential for proper crop development. Each is equally important to the plant, yet each is required in vastly different amounts. These differences have led to the grouping of these essential elements into three categories; primary (macro) nutrients, secondary nutrients, and micronutrients.

Primary Macronutrients play an essential role in improving the yield and quality of crops. Three main elements are nitrogen, phosphorus, and potassium (N, P, and K) and are required in abundance (Table 1 and Figure 1). They must be readily available through soil media or fertilizer. Proper plant nutrition is essential for successful production of agronomic crops.

Among the nutrients, nitrogen (N) is the fundamental nutrient that needs the most for crop production while N deficiencies result in yellowing crop leaves and reduce tillering of cereal crops. Next to N, phosphorus (P) is a vital nutrient for plant growth and productivity that modifies cell division, enzyme activity, and carbohydrate processes (Malhotra *et al*., 2018). Moreover, phosphorus also plays a vital role in cellular processes by maintaining membrane structure, synthesizing bimolecular, and forming high-energy molecules (Malhotra *et al*., 2018).

Role of nitrogen in improving the yield and quality of age-agronomic crops

Nitrogen is the most abundant mineral nutrient in plants. It constitutes 2–4 percent of plant dry matter. Nitrogen is available 79% in the air, but the plant can only be used N in the form of nitrate (NO_3^-) and ammonium (NH4+). Nitrogen is also regarded as the essential component of all proteins and enzymes and further performed in various metabolic processes of energy transformation (Rajasekar *et al*., 2017). Therefore, a sufficient amount of N availability in plants is required, because it is one of the major key factors of crop production (Rajasekar *et al*., 2017). Rhizobium species of bacteria present in the roots of leguminous crops can convert atmospheric nitrogen into plant available compounds. Nitrogen is the most important nutrient and required by the plant in the largest proportion. It is an important constituent of chlorophyll, protoplasm, protein, and nucleic acids. Nitrogen gives dark-green colour to plants and increases the vegetative growth of crop plants. It plays a key role in the preparation of starch in leaves and the production of amino acids.

Nitrogen supply and yield

Nitrogen plays a key role in agriculture by increasing crop yield. Plants contain 15% nitrogen by weight. All plants

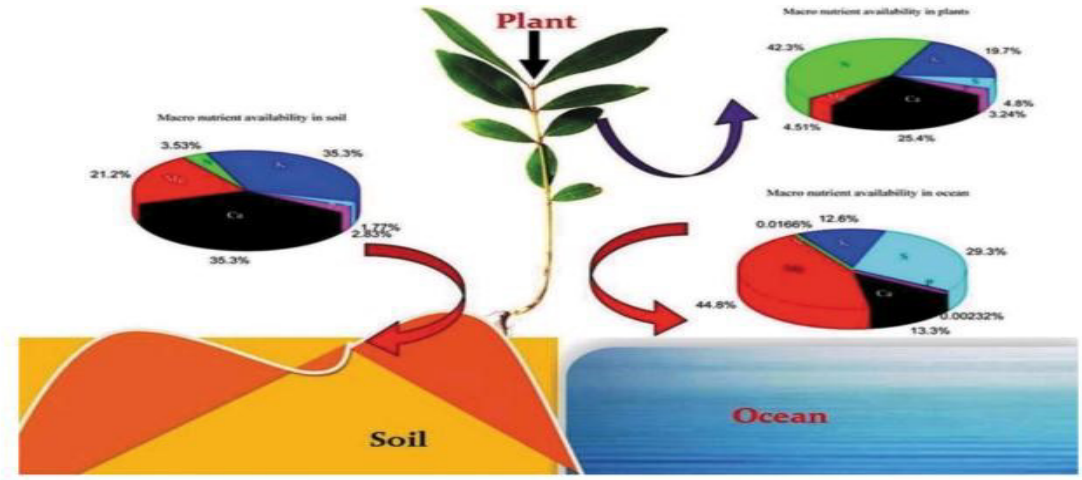

Figure 1: Percent available of macronutrients in soil, plant, and ocean.

Table 1: Primary (macro) plant nutrients, forms taken up and their typical concentration in plants.

Nutrient (symbol)	Essentiality established by	Forms absorbed	Typical concentration in plant dry matter
Nitrogen (N)	de Saussure (1804)	NH_4+, NO^-_3	1.5%
Phosphorus (P)	Sprengel (1839)	H_2PO^{4-}, HPO_4^{2-}	0.1–0.4%
Potassium (K)	Sprengel (1839)	K+	1–5%

including agronomic crops (cereals, cottons, and sugar) produced require a balanced amount of nitrogen for vigorous growth and development process. Nitrogen is showing a fundamental role in enhancing the productivity of four major agronomics crops such as wheat, rice, sugarcane, and cotton. Wheat growth and yield parameters, plant height (cm), number of tillers m^{-2} number of spikelet's $spike^{-1}$, grains $spike^{-1}$ and length of spike and1000-grain weight increased by nitrogen fertilization. Nitrogen at 120kg ha^{-1} showed promising results for plant height of rice, number of tillers, dry weight, length of panicle, number of filled grains, straw yield, biological yield, harvest index, and grain yield 4.66 $tonsha^{-1}$ fertilization (Leghari *et al*., 2016). Nitrogen 100kg ha^{-1}produced more seed cotton yield due to more number of monopodial branches (where from vegetative part develops) and sympodial branches (where from reproductive part develops), boll $plant^{-1}$, average boll weight and 100 cotton seed weight (Chen, 2019). For sugarcane crops, nitrogen is also a backbone and improves the vegetative parts and thus increases the cane weight (Leghari *et al*., 2016).

Nitrogen supply and product quality

Nitrogen not only enhances the yield but also improves the food quality (Leghari *et al*., 2016). It improves the quality of leafy vegetables and fodder and the protein content of food grains. The addition of N generally has the greatest effect on plant growth and a considerable influence on product quality, especially through increases in protein concentration and its quality. It also increases the concentration of several other valuable substances. Various N compounds in plants are important for quality assessment. The concentration of crude protein in wheat grain may be raised from 10 percent to more than 15 percent, thus improving the "baking quality" of the flour. N supply increases the prolamine content in grains, thus increasing the gluten concentration of grain kernels, which improves baking quality (Rajasekar *et al*., 2017).

Role of phosphorus in improving yield and quality of agronomic crops

Phosphorus is an essential macronutrient involved in most growth processes. It is an essential component of most organic compounds in the plant, including nucleic acids, proteins, phospholipids, sugar phosphates, enzymes, and energy-rich phosphate compounds. It has been well reported that P is a necessary component of photosynthetic processes which are systematically implicated in the creation of sugars, oils, and starches and which further helps in the conversion of solar energy into chemical energy, proper plant maturation, and withstanding stress. It helps plants survive in harsh winter

conditions, hastens maturity, and increases water use efficiency. It plays an important role in cell division, and in seed and fruit development. It stimulates early root development, leaf size, tillering, flowering, and grain yield and hastens the maturity of crops. It establishes the plant roots and helps them to go deep for getting moisture and nutrients. Deep roots also form the plant in soil and reduce the loss caused by lodging.

Phosphorus supply and yield

Phosphorus is second only to nitrogen in importance as an essential crop nutrient. It is critical for plant growth, especially in the early jointing stages and for enhancing grain yield and yield components (Ali *et al*., 2014).

In sugarcane, phosphorus is particularly important for root development, early shoot growth and tillering, maximizing early productivity, increasing internodes length and in sugarcane yield and quality.

The addition of phosphorus in cotton increases the growth and yield parameters. The response of number of bolls per plant, boll weight and seed cotton yield was increased (Ahmad *et al*., 2009).

Phosphorus supply and product quality

Phosphorus improve quality in many ways: less grain drying expanse, higher sugar content, less disease loss, improved winter survivability, less dockage, a greater proportion of marketable yield, better feed value, and improved drought resistance in crops such as wheat and maize (KOW and Nabwami, 2015) .Cotton quality components (lint %age, fiber length, and fiber strength) improved from 2 to 5% where phosphorus was added (Ahmad *et al*., 2009).

Role of potassium in improving yield and quality of agronomic crops

Potassium (K) is an essential macronutrient for maintaining crop productivity, but the economic benefit of K fertilizer often has been neglected. One reason for the K deficiency is that K fertilizer always lacks attention, and farmers generally believe that K fertilizer does not effectively increase crop yields compared to N and P fertilizers.

Potassium (K) is an essential plant macronutrient and plays an important role in many physiological processes vital to plant nutrient and water uptake, nutrient transport, and growth, especially under adverse conditions(Jiang *et al*.,2018).

Therefore, it has many functions in plant nutrition and growth that influence both yield and quality of the crop (Kow and Nabwami, 2015).

Potassium supply and yield

Recent studies have shown that K fertilizer application has markedly increased wheat and rice yield. Moreover Potassium has special value to carbohydrate-rich crops such as sugarcane.

Potassium supply and product quality

Potassium not only increases yields but also enhances crop quality. Among plant nutrients, K is very closely associated with crop quality. It is required for good growth as well as for good crop quality, plant health, tolerance to various stresses, and seed quality (Roy *et al*., 2006). It improves the nutritive value of grains by increasing the contents of protein and oil in seeds. With an adequate supply of potassium, cereals produce plump grains and strong stalks. In addition, it increases the resistance to various injuries during storage and transportation, thus extending shelf life.

Conclusion

In conclusion, macronutrients play a essential role in plant growth and development, and thus influence every stage of plant life. From this review, it can be concluded that the primary macro elements (N, P, K,) influence yield and crop quality. Proper plant nutrition, especially those primary macronutrients, is essential for successful production of agronomic crops and plays a key role in agriculture by increasing crop yield. Apart from crop yields, crop quality is another area that needs to be considered with serious attention as it affects human nutrition and profitability of crop products. The common quality attributes that are influenced as reported by many authors include protein and carbohydrate content of the sink organs of plants, grain hardness, and moisture content at storage of crops such as maize and wheat. Undersupplying and oversupplying of nutrients may lead to reduced crop quality.

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