FOLIAR FERTILIZATION - AN INTEGRAL PART OF COMPLEX AND INTEGRATED FERTILIZATIONS – A REVIEW

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Abstract

In the context of demographic increase and climate change, the issue of ensuring food security is becoming increasingly important, which is why the use of chemical fertilizers in agriculture is the main means of increasing the quantity and quality of agricultural production.

Alongside basic mineral (root) fertilization, which is indispensable, foliar fertilization is a measure of increase both in terms of yields and quality.

Foliar fertilizers provide a surplus of fertilizing elements, especially secondary macroelements and microelements, which allows plants to thrive under optimal conditions and to resist stress factors.

Foliar fertilization has become a widespread management tool in directing the nutrition of crop plants, and is often a complementary part of fertilization systems or even seen as an alternative to root fertilization. When applied correctly, foliar fertilization has an interesting potential to manipulate the yield and quality of agricultural production, with low environmental impact and relatively low costs.

This review aims to highlight the importance of foliar fertilization for agricultural crops, based on experimental results from the literature, using the platforms Google Scholar and Web of Science for documentation.

***Key words**: fertilization, foliar fertilizers, macronutrients, micronutrients*

INTRODUCTION

With population growth, the demand for food continues to grow, and the pressure is particularly felt on agriculture as an important branch of the world economy.

In the current context of climate change, which is increasingly stressing agricultural crops and reducing the area under cultivation, the use of chemical fertilisers, which cause crop plants to grow quickly and efficiently, plays an important role in increasing crop yields.

Disadvantages of using higher amounts of chemical fertilizers are environmental pollution, persistent changes in soil ecology, soil physicochemical composition, decreased agricultural productivity and often many hazards to human health.

Fertilisation methods can be based on root fertilisation and foliar fertilisation, depending on how the plants absorb nutrients. Plant utilisation of soil nutrients is affected by a number of factors, including soil temperature, moisture, salinity and microbiota (Li et al., 2009).

When inorganic salts are applied alone or in combination with other fertilizers to the soil, both fixation and antagonism between nutrients occur (Montalvo et al., 2016). For example, excess P can be "fixed" in the soil, where it forms chemical bonds with other elements, including calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn), and becomes inaccessible to plant uptake (Raliya et al., 2018). Therefore, although nutrients may be abundant in the soil, low bioavailability will restrict plant growth and reduce fertilizer use (Xiao et al., 2018), with unused nutrients temporarily accumulating in the soil or being lost to air or water.

Compared to root fertilization, foliar fertilization as an additional fertilization strategy can deliver nutrients directly to the target through the aerial parts of the plants, thus helping to reduce the negative impact on the soil (Bindraban et al., 2015; Fernández and Eichert 2009).

Although foliar fertilizers have traditionally been used to correct nutrient deficiencies, the trend toward foliar spray application is growing (Fernández and Eichert 2009). Foliar fertilization strategies can have greater nutrient use efficiency, reduce negative environmental impacts, and enhance consumer health benefits (Otálora et al., 2018).

Climatic factors are responsible for increasing abiotic stress on crops, leading to reduced agricultural productivity. There are different types of abiotic and biotic stress factors, such as soil salinity, drought, wind, inadequate temperature, heavy metals and various weeds and plant pathogens, which attack plants, reducing crop productivity and quality.

In this respect there is a trend towards the use of biofertilizers, which provide nutrition through natural processes such as solubilization of harder-to-access nutrients, nitrogen fixation, production of hormones, siderophores, various hydrolytic enzymes and at the same time provide crop plants with good tolerance to biotic and abiotic stress.

Foliar fertilisation is an important tool for sustainable and productive crop management and is of significant commercial importance worldwide. Reasons for using foliar fertilizers include: (1) when soil conditions limit the availability of soil-applied nutrients; (2) when high rates of soil-applied nutrient loss may occur; (3) when plant growth stage, internal plant demand and environmental conditions interact to limit nutrient delivery to critical plant organs. Under each of these conditions, the decision to apply foliar fertilizer is determined by the magnitude of the financial risk associated with failure to correct a nutrient deficiency and the perceived likelihood of foliar fertilizer efficacy (Fernandez, V., et al., 2013). Current understanding of the factors that influence the ultimate efficacy of foliar nutrient applications is, however, incomplete (Kannan, 2010; Noack et al., 2010; Fernandez et al., 2013).

This review aims to provide an overview of the effects of foliar fertilizer application in agricultural practice, specifically on highlighting the advantages of high-efficiency foliar fertilizers, so that farmers and agricultural producers have a clear vision of the best agricultural practices aimed at improving soil quality and reducing environmental pollution.

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MATERIALS AND METHODS

The objective of this paper is to highlight the importance of foliar fertilization of agricultural crops, based on the results of experimental research disseminated in the literature. To this end, we studied online publications and scientific articles from specialized journals, using Google Scholar and Web of Science platforms for documentation.

RESULTS AND DISCUSSIONS

The use of organic and mineral fertilisers is one of the main measures to compensate for losses of organic matter and to return nutrients exported from the soil with the harvest. It has been established that optimal fertilisation of the soil ensures the formation of a 25-40% crop increase.

Fertiliser application methods are chosen with great care, depending on the type and condition of the fertiliser, its chemical composition and its physico-mechanical properties.

Foliar fertilisers have attracted increasing attention in recent decades because they offer the most effective way to correct micronutrient deficiencies and increase product yield and quality of crops and plants. Micronutrients are essential for physiological functions in plant metabolism, and leaf uptake has been extensively studied as a biological process, however, the mediating factors are still unresolved (Li Peng et al., 2016).

The rapid development of fertilization methods and technologies using extraradicular and liquid fertilizers has been due to both the possibility of their controlled application according to vegetation phases, crop, agroforestry and nutritional deficiencies, as well as to the increase in the efficiency of fertilization cost - economic result indicators.

Fertilizers with extraradicular (foliar) application must represent solutions/mixtures of homogeneous chemical compounds, with the property of being totally miscible with water, containing essential macro-nutrients (N, P, K, Ca, Mg), as well as micro-nutrients with a significant role in the biochemical processes in plant metabolism (Fe, Cu, Zn, Mn, B, Co, S, Mo and more), stabilized as metal chelates, as well as organic components such as polycarboxylic acids, surfactants and phytoregulators.

Nowadays, in countries with modern, economically efficient agriculture, the use of extraradicular fertilizers has outgrown the concept of supplementary fertilization through the possibility of applying up to 30% of the active substance per hectare.

Advantages of foliar fertilisation

The use of foliar fertilizers is of particular importance in providing microelement nutrition to both intensive crops and other crops grown on microelement deficient soils, due to their strong capacity to assimilate nutrients through the leaves.

Foliar fertilizers are quickly absorbed by plants and commonly are used as nutritional supplements for the plants (Fernandez and Eichert 2009) and as alternative nutrition in conditions when plants show high necessity for nutrients or in cases of deficiency in soil fertility. Foliar nutrition is ideally designed to provide many elements in conditions that may be limiting production at a time when nutrient uptake from the soil is inefficient or nonexistent (Hiller, 1995). The use of foliar fertilizers is becoming increasingly widespread and they are environmentally friendly and target focused, because unlike soil fertilizers, foliar fertilizers are assimilated directly into the organism in small quantities (Fernandez and Eichert

2009). The effectiveness of foliar fertilizers is estimated based on the assimilation and availability of the elements (Lea-Cox and Syvertsen 1995, Zhang and Brown 1999), reduction of phytotoxicity (Neuman and Prinz, 1975), deficiency (Rombolà et al., 2000) and on the yield and the quality of the culture (Dong et al., 2005).

The accessibility of some soil nutrients can be influenced by a number of, often limiting, factors, which is why it can be accepted that nutrient supply through foliar fertilisation is a good strategy, more effective than soil fertilisation, more target-oriented and more environmentally friendly, as nutrients can be applied in controlled amounts and at a certain period of plant growth. The positive effect of foliar fertilisers compared to soil applied fertilisers can be explained by three different mechanisms.

First, nutrient elements can be absorbed directly through the leaves and transported to other organs (Gao et al., 2018), thereby replenishing essential nutrients more quickly and efficiently compared with soil fertilization.

Second, high-potency nutrients can be sprayed at optimum timing and concentrations according to the needs of different crops at different growth stages, which can be more closely matched to the crop requirements compared to soil-applied fertilizers.

Finally, foliar application can be beneficial by exploiting synergistic effects between different nutrients (Bindraban et al., 2015; Xiao et al., 2004).

Under existing scenarios, foliar application of mineral nutrients has become an inevitable agricultural practice for sustainable crop production worldwide. “Foliar nutrition” involves the application of any dissolved mineral nutrient directly to the plant foliage. Foliar fertilization draws attention as a quick, target-oriented, and environmentally compatible insurance to pursue higher crop productivity (White et al., 2015; Malhotra et al., 2020) under optimal and unfavourable growth conditions (Bahrami-Rad and Hajiboland, 2017; Ruiz-Navarro et al., 2019).

As a holistic, foliar nutrition can be widely used to diminish nutritional deficiencies in crop plants at critical growth stages (Pooniya and Shivay, 2013; El-Hady et al., 2020), and biofortification of edible plant parts to address malnutrition of micronutrients (Hidoto et al., 2017; Wang et al., 2017). It is also helpful to minimize the soil barriers for higher nutrient use efficiency (Lizbeth Lopez-Arredondo and Herrera-Estrella, 2012), and advantageous to optimize crop yield, produce quality and reduce environmental concerns, especially nutrients leaching and volatilization losses.

A number of published scientific papers have addressed the mechanism of foliar uptake, efficacy and/or potential of foliar fertilization on agricultural productivity under optimal growing conditions (Fernández and Brown, 2013, Fernández et al., 2013, Fernández et al., 2021, Berry et al., 2019, Fernández and Bahamonde, 2020, Niu et al., 2021); however, the prospects of foliar nutrition in modern agriculture under environmental/climate stress have not been addressed.

The potential of foliar fertilization in improving yield and produce quality under environmental stresses has been provided through meta-analysis, featuring both economic and ecological advantages.

However, foliar fertilisation is forward-looking, and can successfully contribute to achieving and improving food and nutrition security in the current context of multiple challenges facing agriculture. The schematic illustration of the importance of foliar fertilization in this context is also interesting (fig. 1).

The beneficial effects of using foliar fertilisers can be seen directly on the crops to which they are applied, expressed in the quantity and quality of the yields obtained. Indirectly, the benefits of using foliar fertilisers can also be observed on soils by increasing or maintaining their quality.

There is abundant evidence that foliar fertilizers play an active role in improving the quality, yield, and metabolism of crops (Fernández and Brown 2013). Hydroponics experiments showed that leaf application of macro- or micronutrients can effectively alleviate nutritional deficiencies in plants, increase the trace element content of leaves and fruits, improve crop yield, and promote produce quality (Gao et al. 2018; Roosta 2014; Roosta and Hamidpour, 2013).

Recent studies have shown that foliarapplied nano-fertilizers are better than normal salt fertilizers for improving the quality, yield, and metabolism of crops.

In addition to meeting crops' nutrient demand, recent studies have shown that foliar application of nutrient elements can be an effective method to improve the stress resistance of crops.

Leaf spraying enables plants to absorb nutrients directly from their leaves instead of roots, which can reduce the adverse effects of chemical fertilizers on soils and improve the soil environment. Some studies have shown positive effects of foliar fertilization on the soil ecosystem.

The application of foliar fertilizers can reduce salt accumulation in the soil to a certain extent. However, other studies reported increased soil electric conductivity (EC), as some Si fertilizers were not effectively absorbed and utilized by crops after spraying (Xu et al., 2018). Therefore, better fertilization schemes are required to improve crop nutrient uptake and reduce the accumulation of salts in the soils.

Many studies have suggested that the nutrient elements and other constituents of foliar fertilizer formulations may stimulate the uptake of soil-applied fertilizers, which could account for the decrease of salt accumulation in the soil (Junhao Niu et al., 2020).

In summary, foliar fertilization is an effective measure to improve the soil environment and crop quality, especially under restricted soil nutrient utilization and high soil nutrient loss rates (Fernández and Brown, 2013), and when crops are in a special growth period, such as root senescence at the later growth stage.

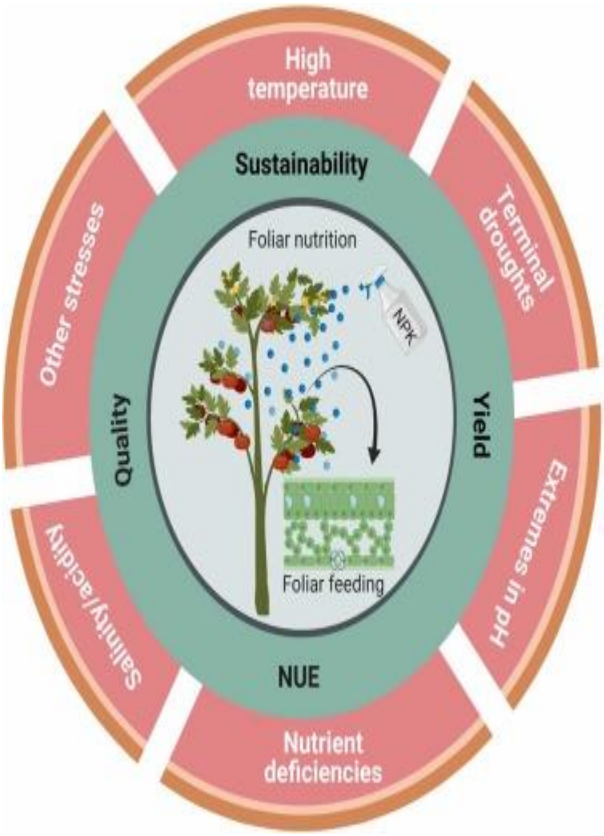

Fig.1. The schematic illustration of significance of foliar fertilization under multifaceted agriculture to bridge gaps to achieve food and nutrition security.
(Source: Muhammad Ishfaq et al., 2022)

Spraying of foliar fertilizers is a fast, efficient, and targeted fertilization method, which can be combined with soil fertilization to reduce the use of chemical fertilizer and soil salinity accumulation. To maximize the effects of foliar nutrition, attention should be paid to the timing and concentration of formulation (including the interactions thereof), according to the characteristics of the crops treated and the soil fertility. Further studies of these issues are still required, especially with regard to the combination of soil and leaf fertilization.

CONCLUSIONS.

Of particular importance in crop fertilisation is foliar fertilisation.

Supplementary foliar fertilisation during vegetation with complex nutrient solutions is part of sustainable agriculture as a main measure to improve plant nutrition under environmentally friendly conditions.

The combination of soil fertilization and foliar fertilization can reduce the use of chemical fertilizers and achieve good production and high yield; thus, use of this combination is an effective measure for alleviating secondary salinization and improving the soil environment.

The optimum quantity and nutrient element application method should be determined according to local conditions and comprehensive assessment of the fertility status of the soil to be cultivated. Systematic studies of the fertilization efficiency of different combinations of root and foliar fertilizers are needed, especially with respect to the interactions between foliar nutrients and soil nutrients, to establish a systematic and scientific fertilization model, promote widespread use of foliar fertilizer in agricultural production, and reduce the ecological impact of chemical fertilizer on the environment.

If applied correctly, foliar fertilisation has an interesting potential to manipulate the yield and quality of agricultural production, with low environmental impact and relatively low costs.

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