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Review Article

REVITALIZING CEREAL CROP PRODUCTION: A CRITICAL REVIEW OF THE EFFECTS OF MACRO AND MICRO-NUTRIENT FOLIAR SPRAYS ON GROWTH AND YIELD

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Abstract *Foliar fertilizer treatment has been identified as a viable source for boosting cereal crop growth and productivity. However, some elements such as application method, nutrient supply, and timing must be taken into account to get the best results. Foliar spray is an effective and focused method of nutrient delivery since it avoids soil shortages and encourages direct absorption through leaves. This review emphasizes the significance of macronutrients for crop growth and development, including nitrogen, phosphorus, potassium, etc. It also looks at how micronutrients like zinc, iron, manganese, etc affect the quantity and quality of agricultural production. Foliar spraying can be a useful method of giving these nutrients to crops, especially during crucial growth stages. To reduce the possibility of causing harm to the crops and surrounding environment, safety precautions should be taken throughout the foliar spraying process. These safety measures include careful nozzle selection, equipment calibration, and cleaning. Overall, the application of foliar nutrients has the potential to result in the production of cereal crops that are more effective and sustainable.*

Keywords*:* *Foliar fertilizer; cereal crop; nutrient delivery; macronutrients; micronutrients; safety precautions; sustainability*

Introduction

Since macro and micronutrients are necessary for cereal crop growth, development, and yield quality, nutrient management is essential for cereal crop production (Marschner, 2012). Macro and micronutrient foliar treatment has attracted attention recently as a practical way to improve crop yield and quality (Mahajan et al., 2016; Liu et al., 2018). Numerous studies have been done to evaluate the effects of foliar application of macro and micronutrients on cereal crops, taking into account elements like the kind of nutrient applied, application method, growth stage of the crop, and soil type. The majority of the outcomes have been favorable, with notable improvements in crop growth and development noted (Singh et al., 2019). This review seeks to present a summary of the most recent findings regarding the effects of applying macro and micronutrients to cereal crops' leaves. This management practice's effectiveness will be discussed, as well as the physiological mechanisms sustaining the crop response to foliar application of macro and micronutrients (Hossain et al., 2018). This review will also point out the difficulties and restrictions that come with applying macro and micronutrients through the leaves, as well as the necessity for future studies to improve this type of management (Shao et al., 2019; Shahzad et al., 2022; Mushtaq et al., 2024).

Pathways of Foliar Nutrient Uptake in Crops

Foliar nutrition is a strategy that is becoming more and more common for feeding vital nutrients directly to the leaves of plants, especially when the soil is weak or quick uptake is necessary. To increase the effectiveness of foliar fertilization, it is essential to optimize the numerous channels through which nutrients are taken up by leaves. The stomata, which are small pores on the surface of the leaf that permit gas exchange, are the main mechanism of foliar

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nutrient intake. These stomata allow nutrients to enter the plant, but how effectively they do so depends on their size, quantity, and the characteristics of the applied solution (Kramer et al., 2007). The cuticle, which is the waxy coating covering the surface of the leaf, is another route through which foliar nutrients are absorbed. The effectiveness of nutrient uptake can be impacted by the cuticle's thickness and composition since it can act as a barrier to nutrient absorption (Marschner, 2012). Furthermore, some nutrients can also enter plants through the leaf epidermis, which is the top layer of cell tissue on the surface of the leaf. As opposed to the stomatal and cuticular channels, this channel's role in nutrient intake is less obvious and is believed to be less significant (Fernández et al., 2013; Abbas et al., 2022; Raza, 2023; Rehman and Uzair 2023;).

To maximize the effectiveness of foliar fertilization, it is essential to comprehend the several foliar nutrient uptake mechanisms. The main methods for nutrient intake are the stomatal and cuticular pathways, but the function of the epidermal system is less clear. The characteristics of the applied solution, the quantity and size of stomata, and the thickness and make-up of the cuticle are only a few of the variables that affect how efficient foliar fertilization.

Conditions that Support Foliar Supplementation

Crop output and product quality can be dramatically impacted by nutrient shortages during crucial growth phases. Foliar supplementation, which delivers nutrients directly to the plant leaves, can swiftly remedy such shortages. Nutrients applied to the soil can only be accessed by plants to a certain extent due to soil characteristics including fixation and leaching; however, nutrients supplied topically can quickly enter leaf cells and reach the cytoplasm. Low and high soil temperatures can also prevent plants from absorbing nutrients, and dry soil conditions can cause nutrients to be lost and plants to wilt. Later phases of plant development make fruit formation the main assimilates sink, which can deprive the roots of energy and reduce growth and production. Nutrient supplementation applied topically to plants during these phases can be very beneficial. Foliar fertilizer addition can dramatically boost crop output and quality, according to recent studies. For instance, a study by Liu et al. (2021) discovered that calcium and magnesium applied topically boosted the yield and caliber of maize. El-Nakhlawy et al. (2020) observed in another investigation that foliar treatment of phosphate and potassium boosted wheat crop growth and yield. Furthermore, a study by Farooq et al. (2021) showed that rice crops grew more quickly and efficiently when nitrogen and sulfur were applied as foliar fertilizers. Foliar supplementation can successfully rectify nutrient deficits, particularly during crucial growth stages, and can enhance crop output and quality. It is a useful strategy for overcoming soil restrictions and environmental challenges that may impair plants' ability to absorb nutrients. To make the most use of foliar supplements in crop management practices, more research is required.

Table 1: Universal used fertilizers for foliar supplementation

Nutrient	Compounds
Nitrogen (N)	Urea (46 % N), DAP (18 % N), CAN (26 % N), ammonium sulfate (21 % N)
Phosphorus (P)	Di ammonium phosphate (46 % P_2O_5), single super phosphate (18-22 % P_2O_5)
Potassium (K)	MOP (58% K_2O), KNO_3 (44 % K_2O),
Calcium (Ca)	Calcium nitrate (19% Ca), MCP, calcium chloride, CAN
Magnesium (Mg)	Epsomite 9.6% Mg, magnesium sulphate
Iron (Fe)	Ferrous sulphate (20 % Fe), ferrous ammonium sulphate (20 % Fe), Fe-EDTA (9-12 % Fe)
Manganese (Mn)	Manganese sulphate (26-28 % Mn), manganese oxide (41-68 % Mn), manganese chelate (12 % Mn)
Copper (Cu)	Copper sulphate (25 % Cu), cupric oxide (75 % Cu), cuprous oxide (89 % Cu), copper chelate (13 % Cu)
Zinc (Zn)	Zinc sulphate (34. 46 % Zn), Zinc oxide (77- 80 % Zn)
Boron (B)	Borax (11 % B), sodium pentaborate (18 % B), solubor (20 % B), boric acid (17 % B)
Molybdenum (Mo)	Sodium molybdate (39 % Mo), ammonium molybdate (54 % Mo)
NPK	20:20:20, 18:18:18

Factors Affecting the Effectiveness of Foliar Supplementation in Plant Nutrition

Foliar supplementation, which offers several advantages including rapid nutrient delivery, a decreased risk of soil-borne illnesses, and convenience, is becoming an increasingly common technique for supplying nutrients directly to plant leaves. The effectiveness of foliar supplementation, which can influence nutrient uptake and subsequent plant growth and development, is, however, susceptible to several variables. The timing of application is one of the important variables that affect how well foliar supplementing works. Depending on the plant type, growth stage, and nutrient requirements, different foliar fertilizer applications should be made at different times. Foliar

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nutrients might become less effective and even poisonous if applied at the incorrect time. For instance, because the plant has already grown the majority of its organs, adding foliar nutrients during the late phases of plant growth may not significantly promote growth (Shi et al., 2021).

The concentration and administration method of the nutrients have a significant impact on how well foliar supplementation works. To guarantee that plants can absorb and use nutrients effectively, nutrient concentration should be optimized. The technique of administration, such as the use of adjuvants or surfactants, can also have a substantial impact on how well nutrients are absorbed by the leaves (Hussain et al., 2021). Temperature, humidity, and light level are a few environmental variables that can affect how well foliar supplementation works. The efficiency of the applied nutrients can be diminished by quick evaporation caused by high temperatures and low humidity. Similar to this, low light levels can affect how well plants absorb nutrients (Alotaibi et al., 2021). In conclusion, several variables, including application timing, nutrient concentration, application technique, and environmental circumstances, affect how well foliar supplementation works. It is essential to carefully take into account these aspects to maximize the efficacy of foliar supplementation and gain the greatest benefits for plant growth and development.

Benefits of Foliar Supplementation

Foliar supplementation has many advantages, including better plant development, increased agricultural output, and improved crop quality. Additionally, when the soil's pH or temperature is unfavorable for nutrient uptake, using this technique can help plants swiftly recover from nutrient deficits. Foliar supplementation is an effective way to increase crop output, according to recent studies. For instance, Ahmed et al. (2021) showed that the yield and quality of wheat crops were greatly improved by the foliar application of zinc and boron. The development and production of maize crops were shown to be enhanced by the foliar application of nitrogen and potassium by Shahzad et al. (2020). Additionally, foliar supplementation can increase plants' ability to withstand stress, especially in the face of challenging abiotic conditions like heat, salinity, and drought. According to Liu et al. (2020), silicon applied topically to rice crops increases their ability to withstand drought conditions by enhancing water usage effectiveness and lowering oxidative stress. In contrast, Wang et al. (2020) found that selenium applied topically improved tomato plants' ability to withstand heat stress by boosting antioxidant activity and lowering lipid peroxidation. Foliar supplementation offers the advantages mentioned above in addition to being affordable, simple to use, and environmentally beneficial. Foliar fertilization should be used to augment soil fertilization rather than to replace it to promote healthy plant growth and development.

Foliar supplementation is a promising management technique for raising plant stress tolerance, addressing nutritional shortages, and increasing crop output..

Foliar Utilization of Macronutrients

Foliar feeding is a good strategy for improving plant nutrition at different growth stages. Direct nutrient administration to the leaves enables rapid nutrient deficiency repair and better crop yield and quality. However, several variables, such as plant species, nutrient availability, environmental parameters, and application rates, affect how effective foliar feeding. Foliar application of nitrogen can supplement soil application of this essential nutrient for plant development and growth. Foliar nitrogen application has been shown to greatly improve crop productivity and quality in recent research (Ali et al., 2019; Mousavi et al., 2020). However, excessive nitrogen application can lead to crop production reduction and leaf burn (Chen et al., 2019). Consequently, it is advised to refrain from going above the suggested dose. Another crucial component for plant growth is phosphorus, whose lack can reduce crop yield and quality. Phosphorus is often applied to the soil as a fertilizer, however, foliar applications of the nutrient can also enhance plant development and yield (Ji et al., 2015; Sanaei-Moghaddam et al., 2017). Nevertheless, several variables, including plant species, treatment rates, and environmental circumstances, have an impact on the effectiveness of foliar phosphorus application. Foliar phosphorus application may not always result in a noticeable boost in yield (Wang et al., 2016).

Another essential component for plant growth and development is potassium, whose lack can reduce crop output and quality. Potassium can be applied topically to plants to help them grow and produce more (Dias et al., 2017; Yang).

All crops need calcium to preserve their quality, and a lack of it can cause them to deteriorate, rot, or turn brown. (Kumar et al., 2016; Zhang et al., 2018) Foliar calcium application can enhance fruit quality and decrease decay and browning in vegetables. Calcium chloride is the folic calcium compound that is applied most frequently. Magnesium is an essential element for plant growth; hence its absence might have an impact on crop yield and quality. To encourage development and yield, magnesium can be given foliar to plants (Wang et al., 2019; Hsieh et al., 2020). However, several factors, such as plant type, treatment rates, and environmental conditions, have an impact on how well foliar magnesium delivery works. To sum up, foliar feeding is a

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successful technique for supplying extra nutrients to plants at various growth phases, enabling prompt repair of nutritional shortages and better crop yield and quality. However, several variables, such as plant species, nutrient availability, environmental parameters, and application rates, affect how effective foliar feeding is.

Foliar Utilization of Micronutrients

In dry and semi-arid areas, foliar fertilization is frequently advised as a solution to micronutrient shortages, such as those in Cu, Fe, Zn, Mn, and B (Abdul Jaleel et al., 2016). Fe^{3+} ions are abundant in neutral and alkaline soils but are not easily accessible to higher plants (Vassilev et al., 2017). Foliar feeding with water-soluble iron compounds is advised to address this. Iron is not easily remobilized in plants, therefore if chlorosis develops, a solution of ferrous sulphate (0.5%) can be repeated every 10 to 15 days (Kumar et al., 2021). Higher soil pH decreases the effectiveness of applying Mn through the soil, while higher DTPA extractable Fe levels in the soil lower Mn availability to plants. It is therefore preferable to apply foliar (Zhao et al., 2016; Abbas et al., 2021; Rehman et al., 2024) feeding of leaves. Light-textured soils, like sandy and loam, are more likely to have copper deficiencies than heavy-textured soils. Organic matter, pH, N, and P levels in the soil are other factors that affect copper availability. While a one-unit increase in soil pH (between pH 7 and 8) produces a 100-fold decrease in Cu availability, organic matter strongly binds copper, limiting its availability (Khan et al., 2019). Cu fertilization applied foliar is a practical solution to these problems. Copper sulphate must be neutralized with calcium carbonate (0.5 kg ha^{-1}) when applied topically to avoid burning the leaves. For foliar feeding, sulphates are safer than oxides, however, copper sulphate is the more economical source (Sohrabi et al., 2016; Khalid and Amjad, 2018; Junaid and Gokce, 2024). Plants growing in high altitudes experience zinc insufficiency.

In soils that are excessively calcareous, sandy, acidic, or yellow, a lack of boron is frequently present. B is easily leached out of the soil and is not translocated inside the plant body, therefore foliar treatment is a good way to make up for its lack. For instance, rice yield was improved by foliar feeding with 0.5% boric acid 35 and 65 days after transplanting (Kumar et al., 2017). To remedy the shortage of Mo in crops, foliar treatment of Mo is advised during the crop's early growth stages, especially in acidic or dry soil environments where foliar application of Mo is preferable to soil application (Singh et al., 2016).

Foliar Feeding In Cereal Crops

Wheat (*Triticum aestivum*)

Among different crops, it has been discovered that wheat responds well to the foliar application of macro and micronutrients, leading to better growth and yield. In their 2015 study, Mehraj et al. examined the effects of foliar applications of zinc (Zn), manganese (Mn), and iron (Fe) on wheat crops and found that both yield and nutrient content significantly increased. The booting and heading stages used a solution of 0.2% Zn, 0.1% Mn, and 0.1% Fe. Similar to this, Aziz et al. (2019) found that applying boron (B) and molybdenum (Mo) to the leaves of wheat at the flag leaf stage at concentrations of 0.5% and 0.1%, respectively, significantly increased grain production and quality parameters.

Additionally, wheat cultivation has shown encouraging results when using a combination of foliar and soil fertilization. According to Fageria et al. (2013), the treatment of nitrogen (N) and sulphur (S) through both soil and foliar pathways led to noticeably higher grain production. In addition to a foliar spray of 2% N and 0.5% S at the pre-flowering stage. The efficiency of the practice is greatly influenced by the type and concentration of the nutrient solution used for foliar application, it is imperative to remember. According to Aziz et al. (2019), smaller concentrations of Mo (0.05%) had a positive effect on wheat growth and yield. Higher concentrations of Mo (0.2%) had the opposite effect.

Rice (*Oryza sativa*)

Numerous studies have been carried out to investigate the impact of macro- and micronutrient foliar fertilization on rice crops. The foliar application of nitrogen (N), phosphorus (P), and potassium (K) at concentrations of 2%, 1%, and 2%, respectively, during the tillering and panicle initiation stages, resulted in a considerable increase in grain production, according to Kumar et al. (2021). Similar to this, Han et al. (2019) showed that applying foliar zinc (Zn) at a concentration of 0.3% throughout the booting and heading stages increased rice yield. Additionally, spraying foliar with micronutrients has demonstrated promising results in rice farming. Wijewardana et al. (2020) showed that applying boron (B) to plants' leaves at a concentration of 0.2% during the growing season significantly increased grain output. To ensure the effectiveness of the practice, it is essential to establish the proper foliar fertilizer doses and concentrations. According to Qadir et al. (2018), rice growth and yield were negatively impacted by the application of a higher concentration of N (3%) through foliar spraying, but a lower concentration (2%) had favorable impacts. Similar to this, Chen et al. (2020) showed that foliar spraying with Zn and molybdenum (Mo) at concentrations of 0.3% and 0.01%, respectively, during the booting stage

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resulted in a notable increase in rice grain production.

Maize (*Zea mays*)

Numerous research have looked into how foliar fertilization affects maize harvests. According to Aziz et al. (2020), applying nitrogen (N), phosphorus (P), and potassium (K) through foliar spraying at concentrations of 1%, 0.5%, and 1%, respectively, significantly boosted maize grain production during the flowering and grain filling stages. In addition, Kaya et al. (2019) discovered that applying zinc (Zn) to the leaves at a concentration of 0.2% during the vegetative and reproductive stages increased maize production and nutrient uptake. Micronutrient foliar spraying has also been reported to have good effects on maize cultivation. In the silking stage, Zou et al. (2021) discovered that foliar application of boron (B) at a concentration of 0.2% considerably boosted maize production. The right concentrations and doses of foliar fertilizers are necessary to get the best outcomes. According to Yaqoob et al. (2019), lower concentrations of nitrogen (N) (1%) had favorable effects on maize development and yield while higher concentrations of N (2%) had detrimental effects. Similarly, Abbas et al. (2020) found that foliar spraying Zn and copper (Cu) at concentrations of 0.2% and 0.05%, respectively, at the tasseling stage increased maize grain production significantly.

Barley (*Hordeum vulgare*)

Foliar fertilization with macro- and micronutrients has been shown in numerous studies to positively affect the growth and development of barley. Rezaei et al. (2017) discovered, for instance, that foliar application of Zn, Cu, and Mn concentrations of 0.5% greatly increased the grain production and protein content of barley. Similar to this, Shereen et al. (2020) demonstrated that applying 1% doses of N, P, and K to the leaves of barley plants greatly increased the plant's height, shoot dry weight, and grain output. Gholizadeh et al. (2021) studied the impact of nitrogen and zinc foliar application on the growth and yield of barley and found that at 2% and 0.5% concentrations of nitrogen, barley's number of grains per spike, 1000-grain weight, and grain yield significantly increased. Depending on the individual nutrient and crop growth stage, different fertilizer doses and concentrations may be employed for foliar fertilization. For instance, foliar application of N, P, and K is advised during the vegetative stage, but the reproductive stage is advised for micronutrients like Zn, Cu, and Mn. Depending on the nutrient and crop stage, the concentration of fertilizers used for foliar application can also vary, ranging from 0.5% to 2%. Malakouti and Kavoosi (2019) assessed the effects of foliar nitrogen and phosphorus application on barley yield and quality in a different study. They found that the application of 2% nitrogen and 0.5% phosphorus significantly increased the number of spikes per plant, spike length, and grain yield of barley.

Oat (*Avena sativa*)

The potential advantages of foliar fertilization on oat crops have been noted in numerous researches. For instance, Khalil et al. (2021) showed that the production and quality of oats were greatly improved by the application of phosphorus and potassium to the leaves at a concentration of 0.3%. Similar findings were made by Sarwar et al. (2018), who discovered that foliar applications of zinc and iron at a concentration of 0.5% greatly enhanced oat plant growth, yield, and nutrient uptake. Khan et al.'s (2019) research also showed that nitrogen, phosphorus, and potassium applied to the leaves of oat plants at a concentration of 0.5% considerably boosted their growth and output. The individual nutrient and crop growth stages determine the proper fertilizer doses and concentrations for foliar application. Normally, potassium, phosphorus, and nitrogen are advised. Foliar fertilization has been demonstrated to boost the crop's nutritional value in addition to enhancing oat growth and yield. Zhao et al. (2020), for example, showed that foliar application of selenium at a concentration of 10 mg/L considerably boosted the selenium content in oat grain, hence improving its nutritional value.

Sorghum (*Sorghum bicolor*)

The effects of foliar fertilization with macro- and micronutrients on the growth and development of sorghum have been the subject of numerous studies. This review summarizes the most recent research on the subject and includes recommendations for the best fertilizer doses and concentrations for foliar application. According to Abid et al. (2020), nitrogen and phosphorus applied to the leaves of sorghum at a concentration of 0.5% considerably boosted grain production and protein content. Similarly, Ojuederie and Adejobi (2021) found that applying zinc and manganese to the leaves of sorghum plants at a concentration of 0.4% considerably enhanced their growth, yield, and nutrient uptake. By applying foliar nitrogen, phosphorus, and potassium at a concentration of 0.5%, Singh et al. (2018) showed the growth and yield of sorghum. Based on the individual nutrient and crop growth stage, different fertilizer dosages and concentrations are employed for foliar fertilization. For instance, micronutrients like zinc and manganese are advised during the reproductive stage, whereas foliar applications of nitrogen, phosphorus, and potassium are advised during the vegetative stage. With concentrations ranging from 0.4% to 0.5%, fertilizers used for foliar application have different concentrations depending on the nutrient and crop stage.

Foliar fertilization has been found to boost the sorghum crop's nutritional value in addition to

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promoting the plant's growth and output. To improve the nutritional value of sorghum grain, Sharma et al. (2019) demonstrated that foliar application of zinc at a concentration of 0.4% considerably enhanced the zinc content in the grain.

Rye (*Secale cereale*)

Li et al. (2020) carried out a study to find out how nitrogen and potassium foliar applications affected the yield and quality of rye. They discovered that adding potassium and nitrogen at a concentration of 0.5% considerably improved rye production and quality. Similar to this, Sallam et al. (2019) found that rye's growth, yield, and nutrient uptake were considerably enhanced by the application of zinc and iron to the plant's leaves at a concentration of 0.3%. The growth and production of rye were greatly boosted by the application of foliar nitrogen, phosphorus, and potassium at a concentration of 0.5%, according to another study by Cai et al. (2018). Depending on the particular nutrient and crop growth stage, the doses and concentrations of fertilizers used for foliar fertilization may change. For instance, it is advised to apply nitrogen, phosphorus, and potassium during the vegetative stage, whereas zinc and iron are advised to be administered during the reproductive stage. In general, the concentration of fertilizers used for foliar application ranges from 0.3% to 0.5%, depending on the nutrient and crop stage. Foliar fertilization can boost rye's nutritional value in addition to boosting its growth and output. Selenium at a concentration of 10 mg/L considerably boosted the selenium level in rye grain, enhancing its nutritional value, according to a study by Alhaj et al. (2020) on the effects of foliar treatment on rye.

Millet (*Pennisetum glaucum*)

The impact of foliar fertilization on millet growth and development has been examined in several studies. According to Kumar et al. (2021), millet yield and nutrient uptake were dramatically increased by the 0.5% foliar application of nitrogen and potassium. Similar to this, Singh et al. (2019) found that millet plants dramatically boosted their growth, yield, and nutrient uptake after receiving foliar applications of zinc and boron at a concentration of 0.2%. Another study by Dauda et al. (2020) revealed that millet growth and yield were considerably enhanced by foliar application of nitrogen, phosphorus, and potassium at a concentration of 0.5%. Based on the specific nutrient and growth stage of the crop, different fertilizers are employed in different doses and concentrations for foliar fertilization. For instance, foliar applications of nitrogen, phosphorus, and potassium are advised during the vegetative stage, but foliar applications of zinc and boron are advised during the reproductive stage. According to the nutrient and crop stage, the concentration of fertilizers used for foliar application also varies, with concentrations ranging from 0.2% to 0.5%. Foliar fertilization can boost millet growth and output in addition to boosting the crop's nutritional value. According to research by Kishore et al. (2021), foliar iron spray at a concentration of 0.5% considerably improved the iron content of millet grain, enhancing the nutritional value of the grain.

Titicale (*Triticale Triticosecale*)

The effects of foliar fertilization with macro- and micronutrients on the growth and development of triticale have been the subject of numerous studies. For instance, Moshi et al. (2021) found that triticale's yield and nutrient uptake were significantly increased by foliar application of nitrogen and potassium at a 0.4% concentration. The growth, production, and nutrient uptake of triticale plants was greatly improved by applying foliar zinc and manganese at a 0.2% concentration, according to Mavropoulos et al. (2019). Furthermore, Wójcik-Gront et al. (2020) discovered that applying nitrogen, phosphorus, and potassium to the leaves of triticale at a concentration of 0.3% considerably increased its growth and yield. Depending on the individual nutrient and crop growth stage, different fertilizers are used in different doses and concentrations for foliar fertilization. For instance, micronutrients like zinc and manganese are advised during the reproductive stage, whereas foliar applications of nitrogen, phosphorus, and potassium are advised during the vegetative stage. With concentrations ranging from 0.2% to 0.4%, fertilizers used for foliar application have different concentrations depending on the nutrient and crop stage. In addition to promoting triticale's growth and yield, foliar fertilization has been demonstrated to enhance its nutritional quality. According to Karimizadeh et al. (2020), foliar iron spray at a concentration of 0.3% considerably boosted the iron content of triticale grain, enhancing the grain's nutritional value.

Restrictions of Foliar Supplementation

The effects of foliar fertilization with macro- and micronutrients on the growth and development of triticale have been the subject of numerous studies. For instance, Moshi et al. (2021) found that triticale's yield and nutrient uptake were significantly increased by foliar application of nitrogen and potassium at a 0.4% concentration. The growth, production, and nutrient uptake of triticale plants was greatly improved by applying foliar zinc and manganese at a 0.2% concentration, according to Mavropoulos et al. (2019). Furthermore, Wójcik-Gront et al. (2020) discovered that applying nitrogen, phosphorus, and potassium to the leaves of triticale at a concentration of 0.3% considerably increased its growth and yield. Depending on the individual

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nutrient and crop growth stage, different fertilizers are used in different doses and concentrations for foliar fertilization. For instance, micronutrients like zinc and manganese are advised during the reproductive stage, whereas foliar applications of nitrogen, phosphorus, and potassium are advised during the vegetative stage. With concentrations ranging from 0.2% to 0.4%, fertilizers used for foliar application have different concentrations depending on the nutrient and crop stage. In addition to promoting triticale's growth and yield, foliar fertilization has been demonstrated to enhance its nutritional quality. According to Karimizadeh et al. (2020), foliar iron spray at a concentration of 0.3% considerably boosted the iron content of triticale grain, enhancing the grain's nutritional value.

Safety measures to be taken during Foliar Supplementations

Nutrients applied topically to plants can significantly improve their growth and development, but to avoid any potential risks, specific safety precautions must be taken. To prevent drift into other fields, foliar treatments should be avoided on hot, windy, and dry days (Wang et al., 2020). To prevent damage to plant foliage when spraying crops, care must be given, and the sprayer must be completely cleaned before use. A suitable nozzle, such as a wide-angle, hollow cone nozzle for ground applicators, should be selected to work within the necessary pressure range of the pump capacity (Wang et al., 2020). The spray nozzle should be calibrated and the boom nozzles should be correctly set to ensure equal spray patterns at a 90° angle to get the appropriate ground speed. It is advised to utilize a greater capacity spray for foliar application of 500 litres of spray liquid per hectare (Sawant et al., 2021). It is advised to run water through the sprayer after usage to get rid of any leftover particles and make sure all the hoses, pumps, and pipelines are clean. For sprayers with stainless steel and plastic elements in particular, rinsing the device with water is crucial to preventing corrosion and damage (Sawant et al., 2021). Additional attention is needed when spraying copper sulphate because it has been discovered to be corrosive to spray equipment (Wang et al., 2020). The spray solution's effectiveness can be increased by adding surfactants, and maintaining the spray solution's concentration is crucial for optimal care (Sawant et al., 2021).

Conclusion

Foliar fertilization is a method that involves spraying water-soluble fertilizers directly onto the leaves of plants to supply them with vital nutrients. The right fertilizer must be chosen, applied in the right concentration, with the right application technique, and at the right time for the plant's growth stage for the procedure to be successful. Nutrient management for plants is made especially advantageous by foliar application since the nutrients are readily absorbed without loss. Foliar feeding shouldn't be postponed until signs of a visual insufficiency manifest, it's crucial to remember. Quality and yield can deteriorate before symptoms show up. Foliar fertilization regularly can help minimize nutrient deficits and lessen the effects of erratic weather.

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Declaration

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All authors contributed equally.

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