Review Article

A comprehensive review onAminochelates: Advances and Applications in Plant Nutrition

Abstract

This comprehensive review explores the advances and applications of aminochelates in plant nutrition, shedding light on their significance and impact in modern agricultural practices. Aminochelates, which consist of metal ions chelated with amino acids, have gained substantial attention for their role in enhancing nutrient uptake and addressing deficiencies in various plant species.The review begins by delving into the fundamental principles of aminochelation and the unique properties that make these compounds highly effective in facilitating nutrient absorption by plants. The interaction between aminochelates and different nutrient elements is examined, providing insights into the mechanisms that contribute to improved nutrient availability in the soil and subsequent uptake by plant roots.Furthermore, the paper discusses the role of aminochelates in mitigating nutrient stress and enhancing plant growth and development. The review incorporates a comprehensive analysis of research findings, including studies on diverse crops, soil types, and environmental conditions. Special attention is given to the safety of aminochelates for plants and the environment, ensuring a balanced evaluation of their overall impact on sustainable agriculture.Additionally, the review explores recent technological advancements and innovations related to the synthesis and application of aminochelates, highlighting emerging trends and potential future developments in the field of plant nutrition. The synthesis methods, application strategies, and their efficacy in different agricultural settings are critically assessed.In conclusion, this review provides a thorough understanding of aminochelates, emphasizing their significance as a promising tool for improving plant nutrition. The insights presented in this paper contribute to the existing knowledge base, guiding future research directions and applications in the realm of sustainable and efficient agricultural practices.

Keywords: **A**minochelates, nutrition, nutrient uptake, sustainable agriculture, etc.

INTRODUCTION

What is chelate?

The word chelate derives from the Greek word “chel”, meaning a crab’s claw, and refers to the pincer-like manner in which the mineral is bound. The term “chelate” was first used by Morgan and Drew.

In 1950 - iron chelates were used to correct Fe deficiency in plant. In fertilizer technology. Chelate refers to inorganic nutrient that enclosed by an organic or synthetic molecule.Chelation is a term that describes an encapsulation process.

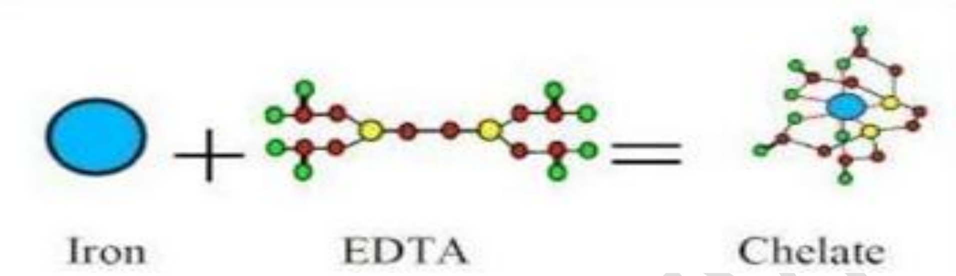


Fig 1. **Structure of Chelate**

Chelating is the chemical process by which a mineral is combined with organic or synthetic molecules. The resulting substances are known as chelates.Chelates easily penetrate plants, proving highly effective in promptly addressing nutrient deficiencies while ensuring the plant's safety.

A chelator or chelating agent is a chemical compound that engages with metal ions, creating durable and water-soluble compounds.

Numerous naturally existing chelating agents, including amino acids, organic acids, humic acids, fluvic acids, lignosulphonates, lignin polycarboxylates, sugar acids, phenols, polyphosphates, flavonoids, and siderophores, are available. Generally more cost-effective, they exhibit functionality across a broader pH spectrum and pose lower toxicity to plants.

What is the difference between complex and chelate?

A complex is an agent capable of forming a connection with a metal ion using either a single atom or multiple atoms. On the other hand, a chelate is an agent that forms a bond with a metal ion using at least two atoms, excluding single-atom bonds. It's crucial to recognize that certain minerals, such as boron or molybdenum, have only one chemical bond, restricting them to the formation of complexes exclusively. Despite this limitation, boron and molybdenum are frequently marketed and sold as chelated minerals in the market (Souri, 2015).

WHY CHELATED MICRONUTRIENTS IN PLANT NUTRITION ?

Micronutrients issues for healthy plant growth:

Soils possessing elevated cation exchange capacity and abundant organic matter have the ability to retain micronutrients, holding them in a biologically accessible and ionic state for plants.

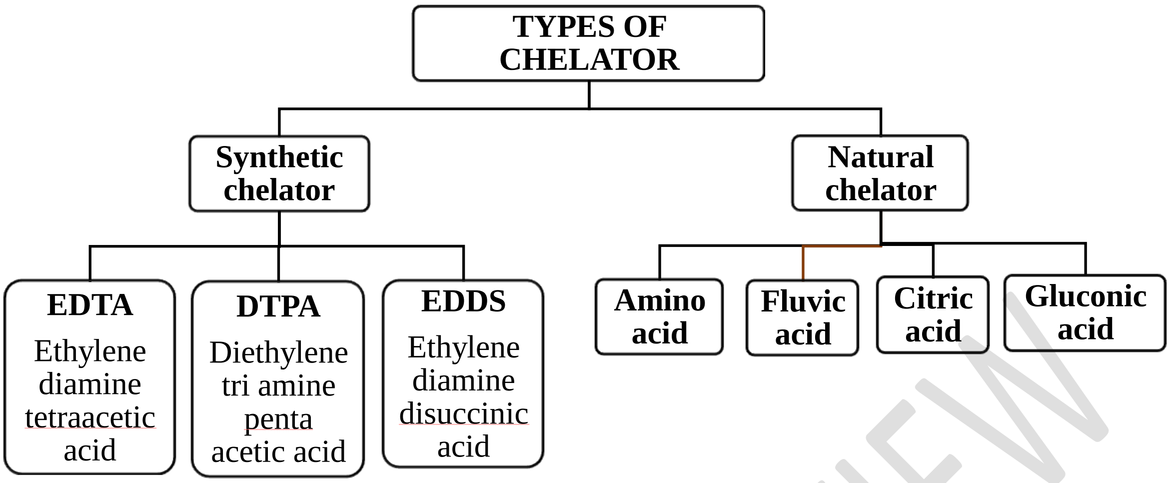
However, not all micronutrient requirements are naturally met, necessitating the application of synthetic micronutrient fertilizers to support plant growth. These micronutrients, when in ionic form, become available to plants within a specific pH range (pH 6.5 to 7.5). Soil with a high pH (above 7.5) reduces the availability of certain micronutrients such as Cu, Fe, Mn, and Zn. Conversely, low soil pH may limit macronutrients like Ca, Mg, and Mo. The application of synthetic micronutrients to the soil can be challenging, particularly in sandy soils or when cultivating crops with high micronutrient demands. Over time, various synthetic and organically chelated micronutrients have been developed to exhibit lower reactivity to soil conditions.

Benefits of chelated micronutrients in plant nutrition:

Chelated micronutrients in fertilizers involve micronutrient ions enclosed by a larger molecule known as a ligand or chelator, which can be either natural or synthetic chemicals. Various chelating agents are employed in agricultural systems to address deficiencies that standard fertilizers cannot rectify. Consequently, synthetic chelates are widely utilized in soil to enhance the bioavailability of micronutrients and increase their concentrations in plant tissues. Soil, being heterogeneous and complex, may render traditional micronutrient applications ineffective due to oxidation or precipitation.

However, chelated micronutrients are safeguarded against oxidation, precipitation, and immobilization under specific conditions. The utilization of chelated micronutrients enhances micronutrient bioavailability, thereby positively impacting crop quality and yield. These chelates are particularly beneficial when plants exhibit micronutrient stress, in alkaline soils with limited micronutrient availability, or when soil micronutrient supplementation proves inadequate.

Fig 2. TYPES OF CHELATOR



ORGANIC V/s SYNTHETIC CHELATE:

Organic chelate shows more penetration rate than synthetic chelate, due to larger molecules such as EDTA, DTPA etc. Organic chelate are biodegraded and non-toxic to the environment, e.g. EDTA form chemically and microbiologically stable complex. Synthetic chelate leads to a threat of underwater contamination and due strong binding capacity cause deficiency of others nutrient.Organic chelate can be used as food source to the microorganism while the synthetic cannot.Organic chelating agent are more stable in comparison to synthetic chelating agent.

How chelate isworks in plant nutrition?

Chelates are molecules characterized by a neutral charge, a crucial attribute. For instance, both calcium and magnesium carry a positive charge. The soil, particularly clay soils, generally bears a negative charge. Consequently, calcium and magnesium are more likely to interact with the soil, rendering them insoluble and unavailable for plant absorption.

Additionally, since calcium and magnesium share the same positive charge, they compete for entry into the plant. Plant leaves contain negatively charged pores, known as stomates, causing positively charged molecules to struggle to penetrate and slowing down absorption at the stomatal entrance. Chelated minerals, owing to their neutral charge, can easily enter these pores (Tabesh, 2020).

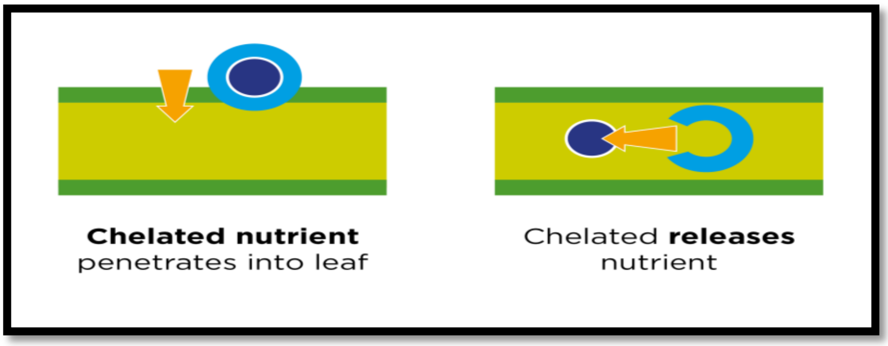


Fig 3: effect of chelate on plant nutrition

Advantages of chelates over tradition forms:

- Chelates are absorbed more readily by plant roots or leaves, requiring significantly lower quantities compared to inorganic compounds.
- Loss of nutrients through leaching is prevented by chelates, and chelation enhances the mobility of nutrients in soil.
- Chelates exhibit easier translocation and assimilation within the plant, reducing competition among minerals, particularly cations.
- Chelates contribute to higher environmental protection by minimizing nitrate and metal ion pollutions.
- Chelating agents safeguard metal ions from undesirable chemical reactions, making chelated iron, zinc, manganese, and copper a preferable method for supplying micronutrients to crops under adverse soil conditions.
- Chelates demonstrate compatibility with a diverse range of pesticides and liquid fertilizers, as they do not react with their components.
- The risk of crop 'scorching' is lower when using chelates due to their organic nature. Additionally, they hinder the growth of plant pathogens by reducing available iron.

WHAT IS AMINOCHELATE?

Aminochelates represent a category of chelate fertilizers derived from amino acids, encompassing both single or multiple micronutrients. Additionally, aminochelates inclusive of macronutrients are prevalent in the market. The synthesis of aminochelate fertilizers involves combining amino acids (typically two to three moles) with metal nutrients obtained from a soluble metal salt (one mole).

These fertilizers, a recent innovation in plant nutrition for agriculture, constitute new formulations produced through the utilization of diverse amino acids, of which there are 20 types. Amino acids, essential components in cell machinery and protein, serve as the foundational elements for amino chelates. These chelates demonstrate systemic behavior within plants, efficiently traveling to target locations due to the plant's recognition of amino acids as fundamental building blocks present in nearly all plant tissues.

Functioning as bi-dentate ligands, aminochelates establish robust chemical bonds with positively charged metal atoms. Amino chelated minerals are more easily digestible compared to their nonchelated counterparts. Once within the plant, the mineral is released, and the residual amino acids forming a protective shell become a source of water-soluble nitrogen for the plant. This ensures minimal wastage, as every component is utilized. Aminochelates are available in liquid or powder forms, commonly employed in organic food production. Their application generally leads to enhanced nutrient uptake efficiency and reduced negative side effects (Mohammadipourand Souri,2019).

Glycine: Good things in small packages:

Glycine chelates, also referred to as glycinates, represent a subgroup within amino acid chelates. Utilized as a chelating agent, glycine, being the smallest amino acid, yields a compact end product that facilitates smoother passage through leaf pores (stomates) compared to larger molecules. This characteristic enhances plant uptake. In wine production, glycine chelates find application not only for delivering essential nutrients but also for providing Yeast Available Nitrogen (YAN). The presence of glycine enables yeast to break it down, utilizing the released nitrogen in the construction of its cell walls.

Quality control factors of aminochelates:

Following production, aminochelates undergo quality control assessments, encompassing several crucial factors:

i. Appropriate molecular weight: While all amino acids possess the potential for aminochelate synthesis, those with a molecular weight ranging from 150 to 200 grams are deemed most suitable. The resultant aminochelate should not exceed 800 Dalton in molecular weight, with a preference for smaller amino acids like glycine. Their diminutive size facilitates easy uptake by plant roots or leaves.

ii. Correct electrical charge: It is imperative that the produced aminochelate maintains electrical neutrality to prevent undesirable chemical interactions before absorption.

iii. High water solubility and plant availability: Aminochelates must exhibit high solubility in water and be readily available to plants, ensuring straightforward metabolism within the plant system.

APPLICATION METHOD:

Amino acid chelates prove highly compatible with greenhouse and hydroponics setups, primarily due to their typical organic certification. They are easily absorbed by plants through both roots and foliage, and they generally do not exhibit phytotoxicity. In hydroponic systems, such as aquaponics, where fish are part of the integrated setup, it becomes crucial to avoid introducing synthetic substances into the fish tissues or meat.

Consequently, opting for organic materials becomes a clear and prudent choice, with amino acid chelates offering a direct application to foliage or nutrient solutions for prompt correction of nutrient deficiencies. Broadly speaking, there are two primary approaches for applying fertilizer in crop systems, involving both soil and foliar methods. Aminochelates represent a viable option for fertilization in both soil and foliar applications as well.

Foliar application:

The application of nutrients through foliar feeding is a valuable method for achieving well-rounded nutrition and maximizing both the yield and quality of agricultural crops, especially in challenging weather conditions. In various instances, the use of foliar spray for fertilizers is favored over soil application, especially when addressing the supply of micronutrients like iron (Fe) and zinc (Zn) in calcareous, saline, or drought-affected soils.

By combining foliar feeding techniques with aminochelate application, there is a notable enhancement in nutrient concentrations within plant tissues, effectively addressing nutrient deficiencies. This integrated approach also proves to be an effective strategy for enhancing plant resistance against a range of biotic and abiotic stresses (Souri *et al.*,2018).

Soil application:

Aminochelates prove to be effective fertilizers for soil use as well. In certain delicate vegetable crops like cucumber or garden cress, applying aminochelates to the soil is preferred over their foliar application, which can induce phytotoxicity on leaves. When applied to the soil, aminochelates facilitate the more efficient uptake of various nutrient elements by plant roots, even those not present in their formulation.

Additionally, aminochelates can be employed through deep and banded placement or in a fertigation system. Their application to the soil contributes to the development of robust soil profiles and enhances biological activity in the soil. Studies indicate that soil microbes exhibit better competition for the reduced forms of nitrogen, such as amino acids and ammonium, over nitrate, compared to plant roots (Souri and Hatamian,2019).

In calcareous soils, whether applied through foliar spraying, soil incorporation, or irrigation water, aminochelates can fulfill the nutrient requirements of plants. This increased effectiveness likely accounts for their greater acceptance among farmers in such regions.

Desirable V/S undesirable characteristic of amino chelated fertilize

- Does not promote other deficiencies
- Formulation is safe for plants
- Organic certification
- Readily available to the plant

▪ Not organically certified
▪ Formulation is prone to burning
▪ Slow uptake
▪ Needs ion replacement to release micronutrient

Why farmers are not ready to use aminochelates fertilizers ?

- **Lack of Awareness:** Farmers might not be familiar with aminochelates or may not fully understand the benefits they offer. Education and awareness programs are crucial to informing farmers about the advantages of using aminochelates.
- **Cost Concerns:** Aminochelates can be more expensive than traditional fertilizers. Farmers, especially those with limited resources, may be hesitant to invest in higher-cost inputs without a clear understanding of the return on investment.
- **Uncertain Performance:** Farmers may be skeptical about the actual performance of aminochelates compared to conventional fertilizers. They may prefer to stick to

methods and products they are familiar with until they are convinced of the efficacy of the new approach.

- **Availability:** The availability of aminochelate fertilizers in certain regions or markets might be limited. Farmers are more likely to adopt new technologies if the products are readily accessible.
- **Compatibility Issues:** Farmers might be concerned about the compatibility of aminochelates with their existing farming practices, crops, or soil types. Compatibility issues can be a significant barrier to adoption.
- **Risk Aversion:** Agriculture is inherently risky, and farmers may be risk-averse when it comes to trying new products. They may prefer proven methods to avoid potential negative impacts on their crops and income.
- **Regulatory Concerns:** Regulatory approval and compliance with local agricultural standards can affect the adoption of new fertilizers. Farmers may be hesitant if there are uncertainties or complexities related to regulatory approval.
- **Demonstration and Trials:** Farmers may be more willing to adopt aminochelates if they see successful demonstrations or trials in similar agro-climatic conditions. Providing evidence of the positive impact on yields and quality can help build confidence.

Several studies related to chelating agents for plants:

Jie *et al.* (2008) observed maximum plant height (38.36 cm), root length (21.38 cm) and dry weight per plant (4.91 g) with application aminochelate-Fe compared to $FeSO_4$ and EDTA-Fe fertilizers.

Datir *etal.* (2012) concluded that among the different treatments, treatment 2.0 % amino acid micronutrient chelate solution gave significantly higher fruit length (10.73 cm), single fruit weight (4.50 g) and yield per plant (623.29 g) and it was at par with treatment 1.5 % amino acid micronutrient chelate solution.

Ghasemi *et al.* (2013) recorded that highest grain yield of wheat obtained with application of aminochelated fertilizers (Zn-glycine, Zn-histidine and Zn-arginine) as compare to other treatment (control and zinc sulphate).

Mohammadi and Hossein (2014) reported that highest shoot dry matter and root dry matter obtained with treatment of Zn-glycine chelate fertilizer under three salinity levels (0, 20, 40 mM). They also reported the highest K concentration and lowest Na concentration in root found with Zn-glycine chelate fertilizer under hydroponic condition.

Saeedi *et al.* (2015) noted that significantly higher fresh weight of flower (306.41 g/plant), dry weight (139.85 g/plant) and vase life (16.72 days) of Cinderella lime by application of Ca-lysine chelate @ (1%) which was at par with Ca-methionine chelate (1%) and Ca-threonine chelate (1%).

Rafie *et al*. (2017) recorded that significantly higher bulb yield and TSS (%) in onion by foliar application of Zn-lysine chelated fertilizer which was at par with all others sole amino acids and aminochelates-Zn fertilizers except control and zinc sulphate treatment. They also reported the significantly higher concentration of Zn in bulb and lowest concentration of nitrate in bulb obtained with foliar application of Zn-lysine chelated fertilizer.

Aslani and Souri (2018) noted that the higher concentration of vitamin C (mg/100 g) in green bean obtained with application of Biomin, Humifolin and DelfonPlus compared to control and NPK application under lime soil conditions. They also reported the highest leaf N content with Biomin application while highest leaf K content with NPK which was at par with Biomin application.

Souri *et al.* (2018) recorded that higher SPAD value (41.6), pod yield (45.1 g/plant), pod protein content (4.9 %) and pod Fe concentration (119.0 mg/kg) in green bean obtained with foliar application of Fe-Glycine @ 500 mg/l than rest of the treatments.

Dhanalakshmi *et al.* (2019) reveled that there was 26.2 % in grain yield (6334 kg/ha) and 14.8 % in straw yield (8806 kg/ha) increase over RDF with treatment chelated micronutrient mixture @ 12.5 kg/ha.

Mohammadipour and Souri (2019) recorded that compared to the control plants, there was a substantial increase of 10 mg/L glycine in the fresh and dry weights of the shoots and roots. Many plant development metrics were lowered by applying 40 mg/L of glycine, but the concentration of proline in leaves rose. All glycine concentrations—aside from 40 mg/L—increased fresh weight of the root. Glycine administered at 10 or 20 mg/L enhanced the amount of protein in the leaf.

Souri and Sooraki (2019) noted that among the different treatments higher number of leaves (9.7), chlorophyll index (34.5), leaf Zn concentration (47.4 mg/kg) and leaf N concentration (2.51 %) of chilli pepper was recorded with application of Biomin under cool temperature condition.

Krishnaraj *et al.* (2020) observed that the application of RDF (250:75:75 NPK kg/ha) +foliar application of 0.2 % Fe-glycinate & Zn-methionate formulation (17:17) gave significantly higher plant height (182.80 cm), chlorophyll content (55.70), grain yield (5932 kg/ha) and dry matter production (14013 kg/ha) in maize at harvest which was at par with treatment RDF + foliar application of 0.2 % Fe-glycinate & Zn-methionate formulation (25:17).

Tabesh *et al.*(2020) concluded that sadri variety found superior than talash variety in bean and higher grain yield was obtained in treatment $ZnSO_4$ but it was at par with treatment Zn-histidine in seed priming.

Zargar Shooshtari *et al.* (2020) noted that among the different treatments, treatment soil application of glycine (500 mg/plant) gave significantly higher plant height (2.8 cm), leaf SPAD value (40), plant economic life (93.0), number of fruits per plant (74), total plant yield (5.3 kg/plant) and same tread also found in leaf protein and nitrate reductase activity in cucumber.

Bashir *et al.* (2021) reported that treatment priming with 1.5% Zn-lysine chelate + inoculation with a consortium of highly ZSB in maize gave significantly higher grain yield (16.64 t/ha and 16.06 t/ha) and biological yield (23.41 t/ha and 23.69 t/ha) in both year 2016 and 2017, respectively than rest of the treatments.

Jawahar *et al.* (2021) recorded that among the different treatments, treatment 1% ferrous glycinate as FS on 25 & 45 DAS in blackgram gave significantly higher value of plant height (52.5 cm), SPAD value (53.7), test weight (6.30 g), protein (24.8 %) and starch (45.3 %).

Kalaiselvan *et al.* (2021)recorded that significantly higher plant height (264.6 cm),leaf length (148.21 cm) and chlorophyll content (56.99) in napier grass at 45 DAC (day after cutting) by treatment of RDF (75:50:40 kg/ha) +soil applicattion of Zn lysinate @ 4 kg/ha + FA of 0.5 % Zn-lysinate at 20 DAC as compared to other treatments.

Kothaipriya *et al.* (2021) reported that significantly higher plant height (192.5 cm), number of leaves (13.2) and leaf area index (5.28) of maize under STCR + soil application of Zn-lysinate formulation @ 7.5 kg/ha + 0.5% Zn-lysinate spray at 30 & 45 days after sowing.

Yeboah *et al.* (2021) noted that maximum plant heightand seed yield of common bean obtained with FA of combination of Zn + Mg aminochelate fertilizer as compared to common fertilizer Zn, Mg and water spray.

Conclusion:

With no negative impacts on the environment, aminochelates are a safer, more effective, and more effective type of fertilizer for plant nourishment. From foregoing discussion, it can be concluded that aminochelates as applied either in soil or foliar in form of natural chelated fertilizer that can increase growth, yield and improve quality of the various crops. Further, application dose and time are also determining the growth, yield and yield attributes of crops. The aminochelates are certainly suitable for specific conditions *i.e.* High soil salinity, lower temperature, etc.

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