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A review on soil fertility and soybean yield improvement by managing micronutrients

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The importance of micronutrients to plant growth is comparable to that of macronutrients such as nitrogen, phosphorus, and potassium, even though they are required at much lower concentrations. They are necessary for the process of cell division, the development of meristematic tissue, photosynthesis, respiration, the transfer of energy and nucleotides, and the overall growth of plants. Although plants only require very modest levels of micronutrients for optimal growth and productivity, the absence of these nutrients disrupts a wide variety of physiological and metabolic processes. It is necessary for plants to receive specific amounts of micronutrients in specific forms at specific times in order for them to grow and develop to their full potential. Lack of micronutrients in the soil significantly reduces soybean production. This article evaluates and summaries information on micronutrient utilization in soybeans at global level. We discussed micronutrient deficiency symptoms and their impact on soybean yields. Micronutrient application methods and dosages are also considered. This study compiled information on micronutrient use in soybean to better understand its impact on fertility, soil health, and grain yield.
Keywords: Micronutrients, soybean, yield, soil fertility, soil health, fertilizer, nutrients uptake, nutrient deficiency.

INTRODUCTION

Soybean (*Glycine max* L.) is one of the most widely cultivated leguminous crops around the globe. In 2020, its global production from a harvested area of 127 million hectares was about 353 million metric tons (FAOSTAT, 2021). Soybeans are farmed throughout the world, but particularly in the Midwest of United states, where they account for nearly 38.5 million hectares (75% of the total agricultural area), second only to maize (*Zea mays* L.) (USDA, 2017). Over 34 percent soybeans and 33 percent of the world's maize are produced in the Midwest of the United States, making it one of the most prolific agricultural areas in the world (FAOSTAT, 2021). The Fabaceae family includes soybeans, which are responsible for providing roughly half of the world's supply of edible oil (Akparobi, 2009). Soybeans are used in many ways, including as food for humans, feed for animal, and industrial materials. In the Pakistan, soybeans are planted in late July and early August and harvested in late October and November. Corn and soybeans are often grown in crop rotation by farmers throughout the country. Even though less than 40% of soybean land receives commercial fertilizer (USDA, 2021), micronutrient deficiencies, poor soil fertility, and low soybean production have developed over the years as a consequence of the excessive use of main macronutrients, notably in corn.

For proper development and reproduction, plants are dependent on a total of seventeen essential nutrients. Carbon (C), hydrogen (H), and oxygen (O) are the three fundamental elements that may be obtained from water and air. Micronutrients include iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl), and nickel (Ni), whereas macronutrients include nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), and

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magnesium (Mg). The need for micronutrients in plants is far less than that for macronutrients. Consequently, micro-nutrient deficits are less frequent than macro-nutrient deficiencies in soybean (Malakouti, 2008), but are nevertheless important for vital cellular functioning. Reduced quality, plant growth, and production due to a lack of micronutrients may have knock-on effects on animal and human health and productivity (Marschner, 1995; Cakmak, 2002; Thapa *et al.*, 2021; Irshad *et al*., 2022). Now, the lack of micronutrients in arable soil is an issue that affects the whole world (Oliver and Gregory, 2015; Monreal *et al.*, 2016).

The micronutrients manganese (Mn), boron (B), zinc (Zn), and molybdenum (Mo) are often the focus of research for soybeans (Mascarenhas *et al.*, 2014; Bender *et al.*, 2015). Researchers and academics have been inspired to investigate the possibilities of yield growth with alternative nutrients due to the widespread use of N fertilizers on maize, wheat (*Triticum aestivum* L.), and other minor grains, particularly after World War II (Bruns, 2017). As a result of increasing nutrient extraction efficiency by high yielding newly developed cultivars, attention in micronutrients has surged in last few years. Plants capacity to take up micronutrients is primarily contingent on the availability of those elements in the soil (Fageria *et al.*, 2009). Micronutrient use with macronutrient application resulted in positive yield responses across a spectrum of crops, including soybean.

Disease and insect invasion, poor fertility of soil, and an insufficient supply of water are only few examples of the environmental pressures that may reduce crop yields (Dimkpa *et al.*, 2017; Adisa *et al.*, 2019). As the adage goes, "if you take care of the soil, it will take care of you," which is why only fertile soil, which has all the nutrients plants need to thrive, can sustain agricultural endeavors. Optimal plant growth, maximum crop output, and long-term soil health all depend on consistent fertilization efforts. Producing food, conserving water, reusing nutrients, reducing greenhouse gas emissions, and protecting biodiversity all depend on soils health (McBratney *et al.*, 2014), which is why they have received increased attention from the scientific community in recent years. In the 1980s, researchers began to consider soil health and soil quality as a means of combating soil deterioration that went beyond traditional methods of increasing fertility. Managing soil health effectively requires knowledge of the physical, chemical, and biological processes of soil, as well as the key nutrients needed to grow crops and sustain the agricultural economy (Fig. 1).

Soil organic matter (SOM) with high concentrations of N and P is made more accessible by legume-based cropping systems (Thapa *et al.*, 2021), which benefits soil fertility and health in a number of ways. Providing organic matter, organic carbon, and Nitrogen (Lemke *et al.*, 2007), legume crops like soybeans may boost SOM by increasing the number of nodule-forming bacteria, Rhizobia (la Favre and Focht, 1983). Legumes help the environment by increasing SOM, enhancing soil structure and permeabilities, nutrients recycling, balancing soil pH, increasing the variety of tiny organisms in the soil, and interrupting the pest and disease cycle (USDA, 1998). When it comes to plant absorption and availability of micronutrients, SOM is key (Rengel *et al.*, 1999). Soil micronutrient availability and solubility may be improved by the presence of organic molecules known as chelators. For example, to successfully transport metal elements like zinc and iron to the root system, it is necessary to chelate these metals with soil organic matter (SOM).

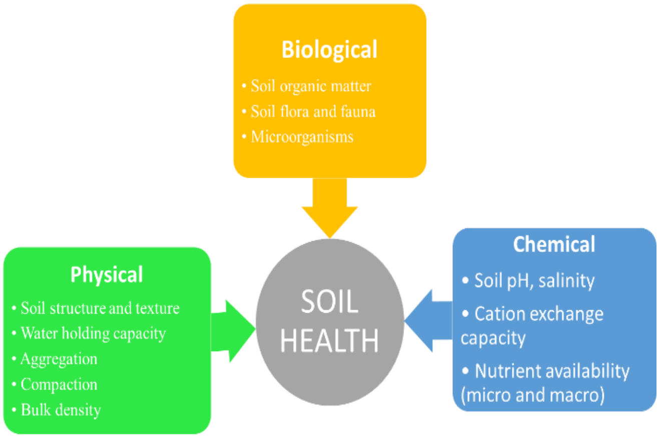

Figure 1. Properties of soil in relation to physical (structure, texture), biological (organic matter, microorganism), and chemical (pH, salinity, exchange capacity, nutrient availability) aspects.

There are several reports on soybean micronutrient management at the level of field, but not many at the level of region (Mallarino *et al.*, 2017). This publication reviews and synthesizes findings from previous research on the use of micronutrients to soybeans from throughout the world. We addressed the symptoms of micronutrient deficiencies and the effects on soybean yields, and we evaluated the literature on the topic. Methods for applying micronutrients and varying the dosages are also taken into consideration. Although we concentrated on research from the Midwest of the United States, which is the most productive location for soybean production in the world, we also reviewed pertinent research from other regions across the globe. The purpose of this review was to compile research about the use of micronutrients in soybean to get a greater comprehension of its significance in enhancing fertility, soil health, and grain output.

***Soil Fertility and Micronutrient*:** Management of nutrient in soil has two fundamental goals, increasing fertility of soil and satisfying the crop nutrient needs of the cultivated crop. Soil fertility enhancement is a crucial agronomic approach for sustainable crop production and economic viability. Soil fauna and flora are an integral part of a healthy soil's ecosystem (FAO, 2008). These organisms work together to reduce the prevalence of harmful diseases and pests, foster mutually favorable symbiotic relationships, break down and recycle vital plant nutrients, and enhance the structure of soil and nutrient withholding capacity.

The proper supply of nutrients, applied at the right time, in the right amount, and in the right location, are all aspects of soil nutrient management plan (Rogers, 2019). The impact of soil nutrients on crop production is central to the role they play in the ecosystem services and soil fertility that depend on it. Organic matter with a high carbon-to-nitrogen ratio (C:N) decomposes more quickly, which has a positive effect on soil health and fertility (Recous *et al.*, 1995). Although some studies have shown that adding fertilizer does not impact the breakdown of high C: N materials, overall, fertilizer application stimulates microbial activity and boosts the organic matter decomposition (Hobbie, 2005). However, increasing SOM in the soil profile over the course of many years by responsible fertilizer usage has been shown to boost soil health, soil fertility, and crop productivity (Ladha *et al.*, 2011; Geisseler and Scow, 2014). Some studies found a correlation between greater rates of SOM application and enhanced availability of micronutrients like manganese and zinc (de Santiago *et al.*, 2008; Motschenbacher *et al.*, 2014; Moreira *et al.*, 2016).

Fertilizers and farming strategies that incorporate crop residue in soil may potentially affect the micronutrients availability in the soil (Wei *et al.*, 2006). In addition to damaging the soil's physical, chemical, and biological qualities, regular use of inorganic fertilizers also leads to environmental contamination (Zhong and Cai, 2007). On the other hand, it has been shown that using organic residues on a constant basis considerably enhances the soil's biological, chemical, and physical qualities and consequently, its health (Chang *et al.*, 2008; Surekha *et al.*, 2010). Thus, crop management plans that aim to boost soil health and crop productivity often advocate for a mixture of organic and inorganic fertilizer applications (Weber *et al.*, 2007; Kumar *et al.*, 2017). Micronutrients are necessary for development and growth of plant, and organic additions including compost, farmyard manure (FYM), green manure, and even incorporating plant residues in soil have been reported to be advantageous (Rengel *et al.*, 1999; Dhaliwal *et al.*, 2019).

Micronutrient availability to plants is also affected by a variety of abiotic and biotic soil variables, including organic matter, redox potential, microbial activity, and pH level of soil (Dhaliwal *et al.*, 2019). Green manure, when applied collectively with organic and inorganic fertilizers, also boosted the content of micronutrients in crops. The SOM functions as a nutrition source, which in turn boosts microbial population, soil organic carbon sequestration, and availability of nutrients to plant (Rengel *et al.*, 1999; Kowaljow and Julia Mazzarino, 2007; Pedra *et al.*, 2007; Sebastia *et al.*, 2007). Therefore, soil organisms play a crucial part in mechanisms such as nutrient cycling, decomposition, N2 fixation, and SOM mineralization (Welbaum *et al.*, 2004). The usage efficiency of fertilizers is improved when synthetic fertilizers are applied with organic manures and crop leftovers (Lamps, 1999).

Soils with a low pH often contain micronutrients whereas, unavailable in soils with a high pH. Figure 2 shows that the optimal availability of Cu, Fe, Zn, B, and Mn occurs between pH 7 and 5, whereas Mo optimal availability occurs at pH values greater than 7. In contrast to molybdenum, the solubility of aluminum and iron increases at low pH (<5). The size and activity of the soil's microbial population, which is responsible for decomposing organic matter and guaranteeing most chemical changes in the soil to make nutrients accessible for plants, is similarly influenced by the soil's pH (USDA, 1998). Micronutrient Deficiency in Soybean

Effects of micronutrient deficiency**:** Visual signs on crops, as well as testing of soil samples and plant tissues, may reveal micronutrient deficiencies. Diseases and pests, herbicide damage, nutritional inadequacies, and unfavorable environmental circumstances are only some of the many potential causes of symptoms in plants including growth retardation and chlorotic leaves (Butzen, 2020). Soybean production may be stunted by a shortage of any of the 17 nutrients necessary for plant growth. Symptoms such as stunned growth, leaf chlorosis and necrosis of stems etc. (Figure 2), of nutrient deficiency appear when nutrient concentrations fall below the adequacy range or critical value, and plants that have reached this state are receptive to application of nutrient (Mundorf *et al.*, 2015). Plants need micronutrients, but only in trace quantities, with optimal concentrations often falling below 100 parts per million (ppm) (Table 1).

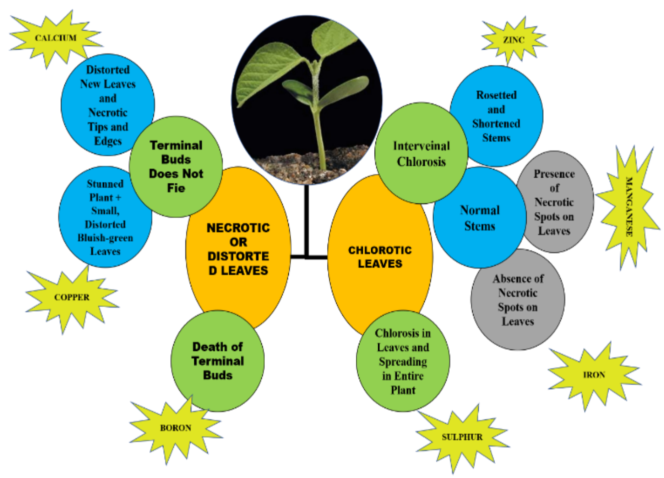

Figure 2. Symptoms of micronutrients deficiencies in plants especially; chlorotic leaves, chlorosis, necrotic leaves, affected terminal buds.

Table 1. Appropriate range and concentrations of plant nutrients like iron, chlorine, manganese, boron, zinc, copper, molybdenum, nickel.

Element	Adequate Concentration (ppm)	Range of Concentrations (ppm)
Fe	100.00	20–600
Cl	100.00	10–80,000
Mn	50.00	10–600
B	20.00	0.20–800
Zn	20.00	10–250
Cu	6.00	2–50
Mo	0.10	0.10–10
Ni	0.05	0.05–5

Hansen *et al.* (2003), Brown *et al.* (2002), Sutradhar *et al.* (2017), Mallarino *et al.* (2017), Bruns (2017)

***Deficiency and availability of different micronutrients iron*:** of Fe is often found in high concentrations in farmed soils, with an average of between 20 and 40 g kg^{-1} soil. However, in semiarid regions where carbonates (soluble salts) do not leach quickly because of limited rainfall, Fe insufficiency is a severe concern in soybean production (Butzen, 2020). Reduced solubility of Fe^{+3} in semiarid conditions hinders its conversion to plant-available Fe^{+2} (Hansen *et al.*, 2003). Soybean leaves, particularly the younger ones, will develop chlorosis between the veins if they don't get enough iron. Brown necrotic patches are seen close to the leaf edge under extreme situations. However, different soybean cultivars have varying degrees of tolerance for iron deficiencies. Even at low levels of deficiency, some cultivars become completely chlorotic, while others exhibit no symptoms. Soybean and other legume crops rely on iron to produce leghemoglobin, a nodular component that shields nitrogenase from oxidation inside root nodules. Therefore, root nodulation and atmospheric N_2 fixation are supported by an appropriate supply of Fe (Bruns, 2017).

Boron: Significant physiological functions of boron include enzyme activity, elongation of cell, synthesis of protein, germination of pollen, production of fruit/grain, and increased yield (Dell and Huang, 1997; Fleischer *et al.*, 1999; Brown *et al.*, 2002). Several horticultural and agricultural crops have been shown to suffer from a lack of boron when grown in either alkaline or severely acidic soil, or when grown in soils with either a very low or very high concentration of organic matter (Table 2). Boron deficiency is unusual in soils like clay but common in coarse, well-drained and sandy soils (Tisdale *et al.*, 1985). Primary cell wall development has been shown to correlate strongly with B availability. To provide just one example, Hanson, (1991) found that about 90 percent of cellular Boron is found in the portions of cell wall. Therefore, early signs of B shortage in plants include cell wall alterations and the middle lamella disorganization (Brown and Hu, 1997). The limited responses to Boron fertilization found in soybean may be attributed to the plant's high tolerance for B shortage. Broadcast applications of about 2.2 kg ha^{-1} of boron have been shown to be hazardous to soybean (Mallarino *et al.*, 2017; Sutradhar *et al.*, 2017).

***Manganese*:** Several variables, including soil organic matter (SOM), pH, calcium carbonate ($CaCO_3$), and redox conditions, affect the availability of manganese (Mn) in soils. Since soybeans are so responsive to the effects of manganese (Mn) deficiency, this nutrient is often in short supply in different parts of the globe (Adams *et al.*, 2000). With low SOM, high pH, and low moisture content soils are more prone to manganese deficiency (Butzen, 2020). Younger leaves show indications of Mn insufficiency as interveinal chlorosis (the veins of the leaves remain green but the regions between the veins become yellow) due to the very immobile nature of Mn in soybean. In some regions, soybean reacted to Mn when cultivated on soils with a pH more than 7.4 (Mallarino *et al.*, 2017), but in others, soils with a medium and fine texture and a pH of 6.5 or above have experienced a manganese deficiency.

***Zinc*:** Zn sensitivity is lower in soybean than in other crops; yet, deficient symptoms are more prevalent in soybean plants grown in soils having low SOM concentration and sandy in nature (Bruns, 2017). Soil erosion contributes to Zn deficiency because it removes topsoil. Because zinc is so poorly mobile in plants, Zn deficiency symptoms manifest first in the youngest and greenest leaves (Bruns, 2017). Stunted plant development and chlorotic leaves, together with

Table 2. Various factors affecting deficiency of micronutrients especially iron, chlorine, manganese, boron, zinc, copper, molybdenum, nickel which is present in soil.

Soil Characteristics Favouring Deficiency of Micronutrients							
Iron (Fe)	**Boron (B)**	**Manganese (Mn)**	**Zinc (Zn)**	**Copper (Cu)**	**Molybdenum (Mo)**	**Chlorine (Cl)**	**Nickel (Ni)**
Acidic soils (pH>7.4) that lack humus and are abundant in soluble salts and/or calcium carbonate. (Hansen *et al.*, 2003)	Arid or wet regions with alkaline or acidic soils (having low rainfall). (Butzen, 2020)	Soils having a moderate to fine texture, a high pH (>6.5), minimal SOM, and limited drainage. (Hansen *et al.*, 2003)	Cool, moist, sandy soils with a relatively neutral pH (6.5). P levels are high. SOM levels are low. (Mallarino *et al.*, 2017)	Extremely leached sand and alkaline peat musk soil with a pH between 7 and 8. (Sutradhar *et al.*, 2017)	Soils with a pH less than 5.8 that have been weathered and leached to a significant extent. (Bruns, 2017)	Occasionally on sandy soils in dry areas. (Mallarino *et al.*, 2017)	Soils poor in extractable Ni. (Adams *et al.*, 2000)

early lower leaf abscission and poor pod set are the effects of a zinc shortage in soybean (Bruns, 2017). Both Zn and Mn have been shown to have antagonistic effects on one another. Soybeans with severe Zn shortages generally have elevated Mn levels in their tissues, particularly their early leaves (Parker *et al.*, 1969; Carter *et al.*, 1975).

***Copper*:** Copper is essential for the production of lignin, which is used to reinforce cell walls. Deficiency symptoms, like with most other micronutrients, often manifest in the form of stunted development or leaf drop in young plants. Light chlorosis throughout the plant, necrotic leaf tips, and a lack of turgor in immature leaves are all signs of a Cu deficiency. Peat musk soils that are alkaline, severely leached, or sandy that have a pH between 7 and 8 are more likely to have a Cu shortage. Copper (Cu) poisoning is more prevalent than the toxicity of other micronutrients (Bruns, 2017) because to the prevalence of Cu as a major element in various pesticides, most notably fungicides. Soybeans exposed to high levels of copper may have impaired protein metabolism and N_2 fixing.

***Molybdenum*:** Plants need molybdenum between 0.2 to 5.0 mg kg^{-1} soil, which is the lowest concentration of any important element. Soils with a pH below 5.8 that have been subjected to severe weathering and leaching have been shown to have decreased Mo availability (Butzen, 2020). When the pH of the soil drops, this causes the molybdenum to strongly adsorb onto the oxides of iron, aluminum, and manganese (Karimian and Cox, 1979; Goldberg *et al.*, 2002). Molybdenum (Mo) is primarily used by soybeans to promote the development of nodules, which in turn aids rhizobia (B. japonicum) in fixing nitrogen (N_2). Therefore, a lack of Mo will have an effect on biological N_2 fixation (Wurzburger *et al.*, 2012; Jean *et al.*, 2013). Soybean plants with a Mo shortage exhibit symptom similar to those of a deficiency of nitrogen, including overall chlorosis symptoms in young plants and chlorotic old leaves.

***Chlorine*:** When it comes to gas exchange, photosynthesis, and disease resistance, chlorine is a key player in the plant world. Chlorosis and withering of young leaves are typical responses to Cl deficit, despite the fact that Cl shortage is seldom encountered. Here, Cl accumulates in the top soil profile due to inadequate drainage, making the soil more hazardous (Yang and Blanchar, 1993; Rupe *et al.*, 2000). In most places with little precipitation, Cl toxicity rather than lack is the main obstacle to successful soybean cultivation. Toxicity due to Cl in soybean was seen in Georgia's poorly drained soils after the application of Cl-containing fertilizer (Parker *et al.*, 1983).

***Nickle*:** Soybeans with a lack of nickel suffer due to low levels of extractable Ni in soil (Freitas *et al.*, 2018). There may be no outward indications of Ni shortage in the leaves of field-grown soybean plants. As a result, the majority of Ni research in plants has focused on toxicity rather than deficiencies (Chen *et al.*, 2009; Yusuf *et al.*, 2011; Muhammad *et al.*, 2013; Reis *et al.*, 2017). Since it is an essential component of the urease enzyme (Dixon *et al.*, 1975), which catalyzes the conversion of urea to ammonia (Witte, 2011; Polacco *et al.*, 2013), plants need a sufficient amount of Ni (Brown *et al.*, 1987) to reach maturity. Because of their reliance on N_2 fixation, legumes may be especially vulnerable to low Ni levels.

***Micronutrients management*:** The degree of the deficit, the development stage of the plant, and the formulation (liquid or dry) of the micronutrient all play a role in determining the most effective mode of delivery. If nutrient deficits are identified well in advance of the growing season, it is best to apply them to the soil. The most common methods of applying micronutrients are via the soil and through the leaves (Fig. 3). Foliar-applied micronutrients often don't have as long-lasting of an impact as those grouped with other fertilizers during planting. Applying nutrients to the soil also speeds up the rate at which they reach the plant (Butzen, 2020).

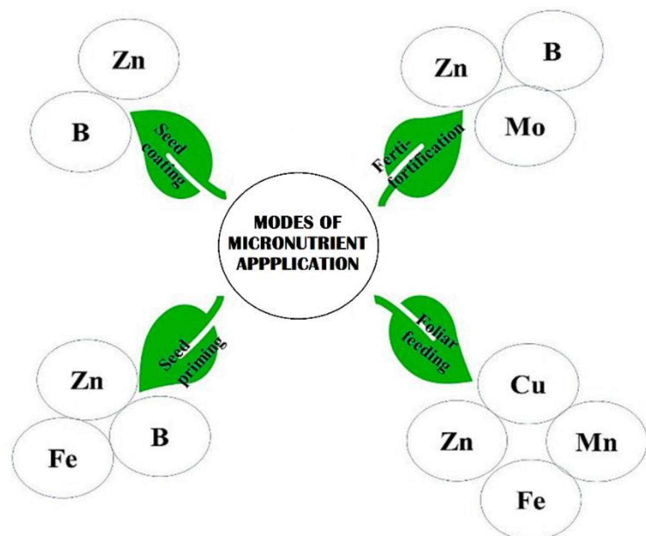

Figure 3. Different modes of micronutrients application (seed coating, seed priming, ferti-fortification and foliar feeding).

Band application close to soybean roots may be useful for micronutrients with low mobility, such as Cu, Mn, Mo, Fe, Cl, B, and Zn. Although nutrients are applied to soil, only a small percentage really enters the plant system; the rest are lost to waste as leaching in soil, which in turn pollutes both water and land (Neumann, 1982). High fixation and limited mobility of nutrients mean that soil-applied fertilizers are not used to their full potential in alkaline and calcareous soil (Zekri and Obreza, n.d.; Rashid *et al.*, 2002). To counter this, foliar spray is the quickest technique to translocate micronutrients in plant organs and deal with the deficit (Boaretto *et al.*, 2002). Disease, insect, and drought resistance are all enhanced by the foliar spray (Vahid *et al.*, 2010). In addition to absorbing light and carbon dioxide, plant leaves may also take in nutrients via their cuticle, cuticular fissures and flaws, stomata, trichomes, and lenticels, all of which have been utilized for a long time in nutrition management (Fernández and Eichert, 2009). Also, unlike with soil treatment, nutrient leaching is reduced or eliminated with foliar spray (Neumann, 1982).

During the flowering initiation and grain filling stages of soybean development, the crop's requirement for nutrients rises, just as it does in many other grain crops. If you apply micronutrients as a foliar spray at this time, you may supplement the soil's nutrition supply. The vast majority of foliar micronutrient supplements are also compatible with most common pesticides and may be applied together. According to a meta-analysis conducted by Joy et al. (Joy *et al.*, 2015), foliar application of Zinc is more effective and cost-efficient than soil treatment for increasing crop Zinc concentrations. Soybeans benefited the most from foliar treatments of Mn when the fertilizer was given during the early bloom or early pod setting stage, or during these phases many times (Randall *et al.*, 1975). Soybean production was not boosted by foliar application of Boron, despite a higher concentration of the nutrient in the grains (Enderson *et al.*, 2015). Soil-applied Mn and Zn increased soybean seed production somewhat, whereas foliar-applied micronutrients reduced seed yield. This is likely owing to some leaf damage produced by foliar feeding. Because of this, the efficacy of foliar micronutrient treatments varies greatly depending on the solubility of the micronutrients and other components such as salts, surfactants, complexes, or chelates (Stewart *et al.*, 2020). Differences in plant performance between soil- and foliar-applied micronutrients are a hot topic of debate (Joy *et al.*, 2015; Dimkpa and Bindraban, 2016).

The use of remote sensing, GIS, and GPS in site-specific (or variable rate) nutrient management has gained popularity among farmers in recent years (Verma *et al.*, 2020). Most studies have focused on macronutrient management at individual sites, whereas research on micronutrient management at specific sites is much rarer, and especially limited in the case of soybean. Soil micronutrient variation reflects the soil's inherent composition and qualities (Eze *et al.*, 2010; Foroughifar *et al.*, 2013; Vasu *et al.*, 2021). The regional variability of soil characteristics, such as micronutrients, was characterized by Foroughifar et al., (2013) using Geostatistics and GIS approaches.

Soybean yield response to micronutrients and uptake**:** Plants need a wide variety of micronutrients, which are necessary yet used in minute amounts. Take-up by crops of major micronutrients is below 2.0 kg ha^{-1} (Fig. 4). Despite this modest need, micronutrient deficiencies impair essential plant activities, leading to irregular plant development, lower yields, and worse quality products. In this scenario, even essential inputs like macronutrients and water may be squandered. Increasing crop yields requires identifying and addressing the primary constraining issue. When this barrier is no longer an issue, the next critical limiting factor will begin to control yields. Step-by-step yield improvements are made until there are no more bottlenecks. Whether intentionally or not, every successful farmer applies this fundamental idea (Siqueira Freitas *et al.*, 2018).

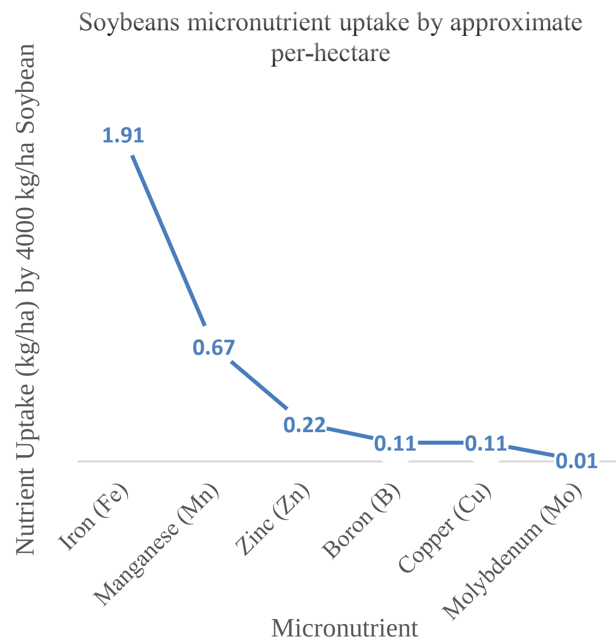

Figure 4. Soybeans, iron, manganese, zinc, boron, copper and molybdenum micronutrient uptake by approximate per-hectare.

Because of variations in available management practices, environmental parameters such as pH, soil mineralogy, moisture, aeration, temperature, and organic matter and soybean genetic resources, the response of soybean yield to micronutrient treatments varied widely between experiments. Therefore, improved nutrient management methods may be implemented if farmers knew more about the genetic and environmental variables influencing soybean micronutrient absorption and crop removal. The use of micronutrients like zinc and iron has been shown to increase agricultural production and yield components (Fox and Guerinot, 1998; Heidarian *et al.*, 2011). Micronutrient usage also assisted plants in mitigating drought's effects. Soybean plants that were sprayed with a foliar fertilizer mixture including iron (Fe) and molybdenum (Mo) were more resistant to damage from water deficits and produced higher yields than the control treatment that did not receive iron (Fe) and molybdenum (Mo) (Heidarzade *et al.*, 2016).

Soybean grain output was not affected by the foliar application of zinc, manganese, copper, or boron, according to research conducted at 40 locations throughout Iowa (Enderson *et al.*, 2015). In contrast, Australian research found that increasing soybean grain production by anywhere from 13% to 208% at various sites with foliar application of Zinc prior to flowering (Rose *et al.*, 1981). In Wisconsin's Mn-deficient soils, applying Mn to both the soil and the foliage improved yield more than either treatment alone (Randall *et al.*, 1975). In the coastal area of Virginia, foliar applications of MnSO4 at a rate of 1.12 kg Mn ha1 throughout the vegetative and reproductive development phases enhanced soybean grain output to as much as 2518 kg ha1 (Mallarino *et al.*, 2001).

Soybean output was not substantially affected by the application of varying concentrations of B, Cu, and Zn when they were sprayed on the plants at the five-leaf development stage in Virginia (Martens *et al.*, 1974) or when they were sprayed on at the same time at 18 sites throughout Iowa (Mallarino *et al.*, 2001). Soybean production was raised by 2.4% in the northern Corn Belt thanks to a foliar fertilizer comprising Zn, Mn, Fe, and B (Orlowski *et al.*, 2016), whereas output fell by 0.7% in the middle Corn Belt. Soybean grain output was not increased and grain quality was only slightly affected by adding B, Cl, Mn, and Zn in Minnesota (Hanson, 1991). Soybean grain protein and oil content were observed to be unaffected by Mn and Zn, and to be very slightly affected by B.

In the case of Cl, deficiency is less studied than toxicity. Cl toxicity results from Cl buildup in the top soil profile, which is particularly problematic on poorly drained soils and in arid regions where precipitation is scarce (Yang and Blanchar, 1993; Rupe *et al.*, 2000). Soybeans produced in Georgia's poorly drained soils, for instance, showed signs of leaf blistering after being fertilized with a Cl-containing fertilizer, likely owing to the toxicity of the compound (Parker *et al.*, 1983). Cl fertilizer was shown to raise the mean trifoliate Cl levels in 60 of the cultivars examined in research conducted in Missouri (Yang and Blanchar, 1993). Ni fertilization boosted soybean output in both the greenhouse and field, but our understanding of the element's role in soybean production is still restricted (Kutman *et al.*, 2013; Lavres *et al.*, 2016).

The effect of micronutrients on soybean output has been shown in various regions. Soybean output was observed to rise from 33.6% to 79.7% in field research done in Brazil by Barbosa *et al.* (2016) using various quantities of fertilizers including micronutrients. Soybean grain production was increased by 18.2 percentage points when Zn and FYM were administered together in India, compared to when these nutrients were applied separately or in other combinations (Vyas M.D. *et al.*, 2003). Soybean production was raised by 11.4% when compared to a control treatment without the addition of Zn. In soybean-wheat cropping systems, Vyas M.D. *et al*. (2003) administered Cu, Zn, B, and Mo through soil and foliar techniques, reporting a considerably higher yield of soybeans with micronutrients, either alone or in combination. Shivakumar and Ahlawat, (2008) discovered that adding 5 kg Zn ha^{-1} together with crop residue and FYM boosted soybean output.

Studies around the globe in different regions**:** Ghasemian *et al.*, (2010) conducted field research in Iran where they applied various rates of Zn, Fe, and Mn to soybean, and they found that applying 40 kg ha^{-1} of Zn and Mn resulted in the maximum grain number, seed weight per plant, pod number, biomass, and grain yield. According to a study conducted by Kobraee *et al.* (2011), using three different rates of Zn (0, 20, and 40 kg ha^{-1}), Fe (0, 25, and 50 kg ha^{-1}), and Mn (0, 20, and 40 kg ha^{-1}), the researchers discovered that the grain yields were significantly higher at 40 kg ha^{-1} of Zn, 50 kg ha^{-1} of Fe, and 40 kg ha^{-1} of Mn. In research using foliar applications of zinc and manganese micronutrients in irrigated soybean, Gheshlaghi *et al.* (2019) discovered that the zinc treatment resulted in a statistically significant increase in yield. Soybean seeds produced higher levels of oleic, linolenic, and linoleic saturated fatty acids after micronutrient administration, notably Zn. (Heidarian *et al.*, 2011) also found that Zn and Fe increased both pod number per plant and grain output. The use of Zn has been shown by (Kobraei *et al.*, 2011) to hasten the production of proteins, RNA, and DNA.

In field research conducted in Pakistan, soybeans were subjected to an analysis of the effect of micronutrients Fe, Mo, and Co, conducted by (Zahoor *et al.*, 2013). There was a 42.3% increase in yield compared to the control group when Fe and Mo were applied to the soybean plants, as well as increases in shoot length, shoot dry weight, nodules per plant, nodules fresh weight, thousand seed weight, and yield. Fe, Mo, and Co may have boosted the number of nodules and yield by activating various enzymes in N_2-fixing bacteria (Hegazi *et al.*, 2011). Using three different soybean cultivars and three different ratios of Fe, Zn, and Mn with phosphorus fertilizer applied as a foliar spray 30 and 45 days after planting, Mohamedin *et al.* (2011) performed a field experiment in Egypt. They found that across all varieties, the quality of the soybean seed increased significantly, as did the yield. Soybean output and quality were both improved because micronutrients have a positive and regulating influence on plant enzymes and metabolism as a whole (Weisany *et al.*, 2014). Russian researchers found that increasing the 1000 seed weight of soybeans by foliar applying liquid Cu fertilizer during the early boom stage (Kolesar *et al.*, 2020). Soybean plants in Ukraine were able to produce more pods and seeds after receiving a foliar spray of fertilizers with a high concentration of Mo, Mn, and B (Novytska *et al.*, 2020).

Conclusions**:** A farm needs a long-term strategy for managing soil fertility. The only way to maximize yield is if there are sufficient supplies of nutrients for the plants to use. Thus, plant health, and by extension animal and human health, depends on the fertility and health of the soil. Soybean response to micronutrients is influenced by several variables, according to research. These include geographical location, soil type, soil pH, cultivar, rainfall/irrigation frequency, and the presence of SOM. Soybean nutrition management relies heavily on knowing when, when, how much, and what kind of fertilizer to apply to maximize output. Soybean production was often increased when micronutrients were administered to the soil or foliar at the rates suggested by soil test findings. Plant tissue analysis has been shown to be important in certain research; nevertheless, it is only applicable for identifying nutritional deficiency issues during the crop growth season. Therefore, in addition to routine soil testing, it is advised to do plant analysis. Research on how foliar applications of micronutrients affect soybean yields has often shown contradictory findings. Therefore, extra foliar feeding should only be considered if it won't significantly increase the cost of output. To maximize revenues and minimize nutrient waste, studies are required to assess the viability of variable rate technologies in micronutrients on a site-specific basis.

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