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Revolutionizing Hybrid White Corn Yield: The Synergy of Dolomitic Lime, Magnesium, and Zinc in Asian Productivity

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ABSTRACT

Hybrid white corn has emerged as a strategic staple alternative in Asia, where rising population pressures, soil degradation, and micronutrient deficiencies increasingly threaten food security. Among the constraints, acidic soils dominate vast agricultural landscapes, significantly limiting productivity due to low pH, aluminium toxicity, and nutrient deficiencies, particularly of magnesium (Mg) and zinc (Zn). This review comprehensively examines the synergistic effects of dolomitic lime, Mg, and Zn on the physiological and agronomic performance of hybrid white corn, emphasizing their roles in overcoming soil acidity, enhancing nutrient availability, and optimizing plant function. Dolomitic lime, rich in calcium and magnesium, ameliorates soil acidity while improving nutrient exchange and microbial activity. Magnesium, a central component of chlorophyll and enzyme activator, supports photosynthesis, carbon fixation, and stress resilience. Zinc, vital for protein synthesis, growth regulation, and enzymatic activity, is often deficient in acidic soils but becomes more bioavailable following liming. The integrated application of these amendments significantly improves biomass accumulation, root development, chlorophyll content, and ultimately, grain yield. Field trials across Asia and comparable agroecological zones demonstrate substantial yield gains and improved soil fertility under combined applications. By synthesizing current literature and empirical findings, this review provides actionable insights for nutrient management strategies in acid-prone soils. The synergistic amendment approach presents a scalable, sustainable solution to enhance hybrid white corn productivity and soil health, contributing to food security and agricultural resilience in Asia's dynamic cropping systems.

Keywords: hybrid white corn, dolomitic lime, magnesium, zinc, soil acidity, yield improvement

INTRODUCTION

Maize (*Zea mays* L.) ranks among the most extensively cultivated agricultural commodities globally, following rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.). It serves as a fundamental component for ensuring food security in some of the most economically disadvantaged areas across Africa, Asia, and Latin America, and is cultivated across nearly 100 million hectares in 125 developing nations (Tandzi, et al., 2018).

Hybrid white corn is becoming a major crop globally and in Asia. It is seen as a promising staple food substitute due to its resilience to environmental challenges. In Asia, it is a strong alternative to rice because of its similar physical, chemical, and sensory qualities. This makes it appealing for regions looking to diversify food sources while maintaining cultural preferences. By using improved hybrid white corn and proper fertilization, grain yields can triple compared to local varieties. This shows hybrid white corn's significant potential to boost food security and agricultural productivity in Asia and worldwide (Lee et al., 2015).

Despite its potential, corn cultivation, especially hybrid white corn, encounters major obstacles, especially in acidic soils. Acidic soils are common in various areas, such as certain regions in Asia and Africa, and are defined by their low pH levels, which can impede plant development and decrease yields (Hayati et al., 2014). It is also identified as the primary factor leading to the low yields observed in maize-producing areas of Angola (Nginamau et al., 2024). As stated by Tandzi et al (2018), one significant abiotic challenge in corn production is the prevalence of acidic soils, resulting from a low pH level causing yield losses of up to 69%. Low pH acidic soils can lead to aluminium (Al), manganese (Mn), or iron (Fe) toxicities. Various studies have documented notable decreases in maize grain yield associated with low soil pH.

The advancement of food crops in acidic dry soil is still falling behind because of constraints such as low nutrient levels, low pH, and aluminium toxicity. To satisfy the growing demand for corn, both in the domestic market and for export, it is essential to keep working towards enhancing corn productivity (Azrai et al., 2023). The need for soil amendments such as dolomitic lime, magnesium, and zinc to enhance the productivity and yield of hybrid white corn in Asia is underscored by the challenges posed by acidic soils prevalent in the region. These amendments play a crucial role in improving soil chemical properties, which in turn can significantly boost corn yield and quality. Dolomitic lime, comprising both calcium and magnesium, is efficient in counteracting soil acidity and enhancing soil structure. In Indonesia, the use of dolomite on acidic upland soils raised soil pH and concentrations of vital nutrients such as Ca and Mg, resulting in greater maize yield and biomass (Kasno et al., 2023). Dolomite has a theoretical equivalent ratio of Ca and Mg of 1:1 based on $cmol \cdot kg^{-1}$. Its application reduces the soil Ca/Mg ratio (Takamoto et al., 2021). This highlights the need for precise management of these nutrients to optimize corn production. Additionally, zinc plays a crucial role in the growth of maize, particularly in soils that lack sufficient zinc, which is often the case in Asia. Research conducted in Pakistan and China has demonstrated that applying zinc to the soil and leaves can greatly enhance both the yield of maize and the zinc content of the grains (Sarwar et al., 2017). Ideal levels of zinc are essential for maximizing yields and enhancing the zinc content in maize, which is vital for combating micronutrient deficiencies in human nutrition (Liu et al., 2017).

Thus, this literature review aims to comprehensively evaluate and synthesize existing research on the synergistic effects of dolomitic lime, magnesium, and zinc on hybrid white corn. The central focus is on enhancing corn productivity and yield within Asian agricultural systems by assessing how these soil amendments individually and collectively influence critical agronomic and physiological parameters like biomass, chlorophyll content, and root development. Furthermore, the review will analyze their effectiveness in improving soil fertility and overall productivity, particularly in the acidic soil conditions prevalent across various Asian regions.

METHODS

This review article employed a systematic and integrative literature review methodology to evaluate and synthesize existing research on the agronomic and physiological impacts of dolomitic lime, magnesium (Mg), and zinc (Zn) on hybrid white corn productivity in Asian contexts. The review was designed to ensure comprehensiveness, scientific rigor, and relevance to current challenges in soil fertility and crop production across acid-prone agricultural systems. Emphasis was placed on identifying both the individual and synergistic effects of these amendments on key growth parameters and yield outcomes. Particular attention was given to field-based studies conducted in tropical and subtropical regions, where soil acidity is a persistent constraint to sustainable maize production.

Research Design and Scope

This review adopted a narrative literature review approach aimed at synthesizing the current state of knowledge on the effects of dolomitic lime, magnesium (Mg), and zinc (Zn) on hybrid white corn productivity, with a particular focus on acidic soils commonly found in Asian agricultural systems. The methodology emphasized breadth and depth of analysis by integrating empirical findings from agronomic, soil science, and plant physiology domains.

The study was guided by central thematic objectives to explore the interactions among dolomitic lime, Mg, and Zn as soil amendments and their impacts on the individual and combined effects on hybrid white corn yield, physiological parameters such as chlorophyll content, root development, and biomass, and soil fertility enhancement and nutrient availability in acid-prone agroecosystems.

Relevant literature was critically selected based on thematic relevance, scientific credibility, and empirical strength, with emphasis placed on studies that involved field trials, regional agronomic practices, and nutrient management strategies in tropical and subtropical Asia. Cross-regional comparisons were also considered where applicable (e.g., Latin America and Africa) to highlight transferable insights under similar soil constraints. This design enabled the identification of research trends, knowledge gaps, and best practices for optimizing hybrid white corn performance through integrated nutrient management in acidic soil contexts.

Literature Search Strategy

An extensive and targeted literature search was conducted from January to May 2025 using multiple academic databases, including Scopus, Web of Science, ScienceDirect, Google Scholar, AGORA, SpringerLink, and Wiley Online Library. The search strategy focused on retrieving studies that examined the effects of dolomitic lime, magnesium (Mg), and zinc (Zn) on hybrid white corn productivity, particularly within acidic soil contexts across Asia. Keywords and search terms used in various combinations included “hybrid white corn,” “Zea mays,” “dolomitic lime,” “magnesium fertilization,” “zinc application,” “acidic soils,” “soil fertility management,” and “Asia.” Boolean operators and truncations (e.g., "dolomite AND maize AND yield") were applied to refine results, increase sensitivity, and capture studies using alternate terminologies. To ensure thorough coverage, a manual search of reference lists from relevant review articles and meta-analyses was also conducted to identify additional primary studies not retrieved through database queries.

Inclusion and Exclusion Criteria

Studies were selected based on specific inclusion and exclusion criteria to ensure relevance and scientific merit. Included materials comprised peer-reviewed journal articles, technical reports, and academic dissertations published between 2000 and 2025. To align with the review's thematic focus, studies had to investigate the impact of dolomitic lime, magnesium, and/or zinc on hybrid white corn or closely related maize varieties. Priority was given to research conducted in Asian countries or in agroecological zones with comparable acidic soil profiles, such as those in Latin America or sub-Saharan Africa. Additionally, selected studies were required to present empirical data on soil chemical properties, plant physiological responses, or yield outcomes, and all reviewed materials were restricted to the English language. Excluded from consideration were non-empirical works such as opinion pieces, editorials, and conceptual essays; greenhouse or hydroponic studies lacking field validation; and studies focused solely on transgenic corn unless they provided relevant insights into nutrient interaction dynamics.

Data Extraction and Categorization

For each eligible study, a standardized coding sheet was used to systematically extract relevant data points. Key variables documented included the study location and agroecological context; the type, rate, and method of application for dolomitic lime, magnesium, and zinc; and the timing of soil amendment treatments. Agronomic and physiological metrics such as chlorophyll index, biomass accumulation, and grain yield were also recorded, along with detailed soil characteristics before and after treatment application (Ohagan et al., 2023). Particular attention was paid to any documented synergistic or antagonistic nutrient interactions, as well as insights on economic viability or cost-effectiveness. To enable meaningful analysis, studies were grouped into three thematic categories: soil chemistry and amendment interactions, plant physiological responses, and agronomic or economic outcomes. Additionally, a focused subgroup analysis was conducted on studies specifically addressing the effects of nutrient interventions in acidic soils, micronutrient-deficient systems, and high-density hybrid corn production settings. This structured approach follows established data extraction protocols in research, such as those employed by Travero et al. (2025) and Nagal et al. (2024) in their investigation of performance factors in various parametric aspects.

Critical Appraisal of Studies

To ensure the reliability and relevance of the synthesized findings, each included study was critically reviewed based on general academic standards and thematic alignment with the objectives of the review. The appraisal focused on evaluating the soundness of the study design, the clarity and completeness of treatment descriptions, and the appropriateness of the data presented in relation to hybrid white corn performance under acidic soil conditions. Consideration was also given to the rigor of reported methodologies, the credibility of data sources, and the extent to which results were supported by empirical evidence. Studies were further assessed for their applicability to Asian agricultural systems, particularly those dealing with common soil constraints such as acidity and micronutrient deficiencies. Only studies that demonstrated methodological coherence, empirical depth, and contextual relevance were included in the final synthesis. This critical evaluative lens aligns with frameworks adopted in regionally grounded knowledge studies, such as the cross-cultural appraisal of indigenous agricultural systems by Nagal (2025).

AGRONOMIC IMPORTANCE OF HYBRID WHITE CORN

Global and Regional Production Trends

The production trends of hybrid white corn in Asia reveal significant growth and regional variations, with key countries leading in output. Hybrid white corn, recognized for its potential as an alternative staple food, has seen increased adoption due to its favorable characteristics and high yield potential. Asia accounts for approximately 31% of global maize production, with a notable annual growth rate of 3.1% from 1993 to 2013 (Zaidi et al., 2018).

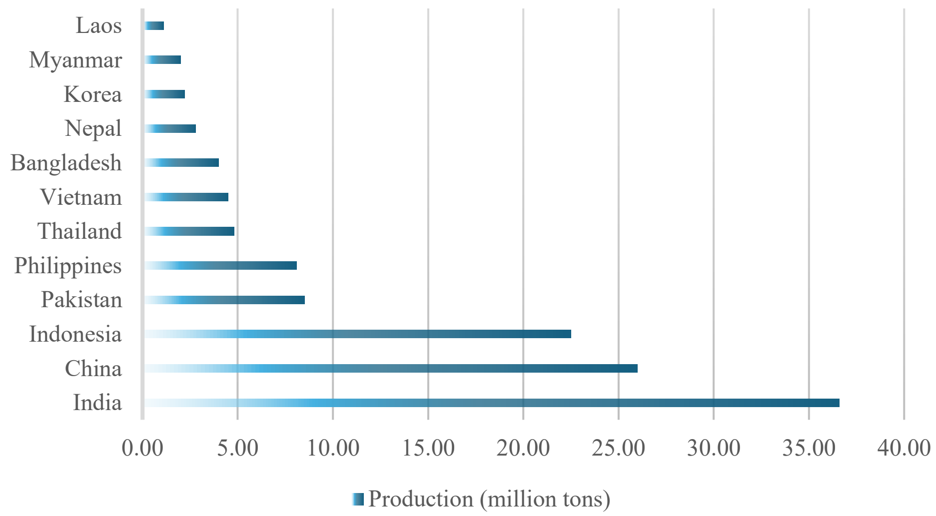

Figure 1: Asia-Pacific average corn production (million tons) in 2020

In the Asia Pacific region, over 30.1 million tons of maize were produced in 2020 (Fig. 1), with India producing the most of any country with 36.60 million metric tons (USDA, 2025). This was followed by China with 26 million tons, Indonesia with 22.5 million tons, Pakistan with almost 8.5 million tons, and the Philippines with around 8.1 million tons. Thailand ranked 6th with a total production of 4.8 million, followed by Vietnam with 4.5 and Bangladesh with 4 million metric tons. Nepal, Korea, Myanmar, and Laos preceded the list with 2.8, 2.2, 2, and 1.1 million metric tons, respectively. Indonesia is notable for developing hybrid varieties and increasing local production while Vietnam is primarily an importer, yet it has developed local varieties to improve production efficiency (Lee et al., 2015).

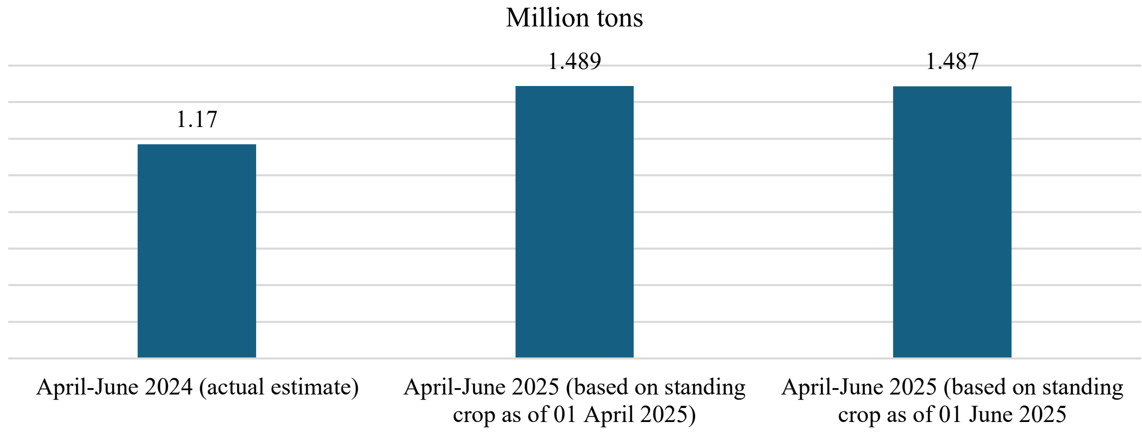

Figure 2: Corn Production estimates in the Philippines, April-June 2024-2025

The estimated corn production based on standing crops for the period April to June 2025 as of 01 June 2025 may increase to 1.487 million metric tons or by 26.7 percent from its actual estimate of 1.17 million metric tons in the same period of 2024. Meanwhile, the updated estimate of corn production based on standing crops as of 01 June 2025 indicated a decrease of 0.1 percent from its record of 1.489 million metric tons as of 01 April 2025 (PSA, 2025).

Table 1. Corn: April-June 2025 Estimates and Actual Data as of 01 June 2025

APRIL-JUNE						
Item	**2024 Actual Estimate**	**Based on Standing Crops**		**Percent Change**		**Actual Production, Area Harvested & Yield**
		As of 01 Apr 2025,	**As of 01 June 2025,**	**01 June 2025/2024 Actual Estimate**	**01 June 2025/01 Apr 2025**	**As of 01 June 2025,**
PRODUCTION (mt) White Yellow	1,174,034 230,276 943,758	1,489,368 258,860 1,230,508	1,487,370 258,955 1,228,415	26.7 12.5 30.2	-0.1 a -0.2	1,294,828 172,555 1,122,273
HARVEST AREA (ha) White Yellow	346,877 122,922 223,956	402,879 129,753 273,126	402,726 129,599 273,126	16.1 5.4 22.0	b -0.1 -	330,681 85,982 244,699
Yield (mt/ha) White Yellow	3.38 1.87 4.21	3.70 2.00 4.51	3.69 2.00 4.50	9.2 7.0 6.9	-0.3 - -0.2	3.92 2.01 4.59

- - no change
a - less than 0.05 percent increase
b- greater than-0.05 percent decrease
Sources: Philippine Statistics Authority, Com Production Survey and Monthly Palay and Com Situation Reporting System

Harvest area based on standing crops for the period April to June 2025 may increase to 402.73 thousand hectares or by 16.1 percent from the 346.88 thousand hectares actual estimate of harvest area in the same period of 2024. Similarly, the yield per hectare of corn may increase to 3.69 metric tons or by 9.2 percent from its previous year's same quarter record of 3.38 metric tons. As of 01 June 2025, about 330.68 thousand hectares or 82.1 percent of the 402.73 thousand hectares updated harvest area of standing corn have been harvested, translating to 1.29 million metric tons of corn output (PSA, 2025).

Economic and Nutritional Significance

With a global per capita consumption of 135.7 kg/year, the maize crop ranked number one in consumption and second in production after sugarcane, as Saini et al. (2020) mentioned. Corn, considered the most popular cereal crop in the world, is grown by most countries, but China provides half of the international market together with the United States (Tanklevska et al., 2020). In 2021, China is one of the top two consumers of corn, buying about 845 million bushels. Most corn utilization is through converting it into ethanol, used as animal feed, or used to make high fructose corn syrup with China, ranking second in consumption, accounting to 11, 574 million bushels while India with over 1,100 million bushels. It was preceded by Egypt, Japan and Vietnam, with 661, 650 and 624 million bushels, respectively (Statista, 2023).

One hundred of the 2000 various sorts of products made from corn are present in every element of human life. Most of them are utilized in various industries, including those that produce food, medicine, everyday items, industrial goods, animal feed, and others. According to international researchers, the world's maize market will increase by 25% and reach 1.191 billion tons by 2026. The world's population is expected to rise by 3 billion by 2050, and the demand for maize products in Asian nations will rise by 53% until 2026 compared to equivalent indicators in 2016. These two factors will serve as the driving force behind output expansion. On a worldwide basis, it is anticipated that the Asia-Pacific areas will continue to have significant demand for the next following years. Hence, the continuously expanding worldwide population will spur market expansion for corn in the coming years. Also, people's choices for diet items high in protein alter due to a greater general understanding of adequate nutrition and healthy lifestyles. This suggests a rise in food grain demand for various crops, including maize, which encourages the expansion of the global market for this commodity. (Tumamang et al., 2017; Tanklevska et al., 2020).

Since maize is fundamentally a plant that produces carbohydrates, it is a significant energy source for both humans and animals. Maize contains roughly 72% carbohydrates, 10% protein, and 4% fat, providing an energy density of 365 Kcal/100 g (Ranum et al., 2014). Protein is an essential element for human growth and development. Humans need 0.66 g of protein per kilogram of body weight every day to support healthy growth and development and make up about 20% of the human body and are essential to practically all biological functions, as stated by Hossain et al. (2019). Corn is a nutrient-rich cereal, packed with B vitamins (B1, B2, B3, B5, B6) beneficial for heart, brain, digestion, and skin health. It also contains vitamins C, A, and K, along with beta-carotene and selenium, which support healthy thyroid and immune system function. Vitamin A's antioxidant properties help protect against diseases like cancer by counteracting free radicals, while vitamin E offers anti-aging benefits and vitamin C boosts immunity. Additionally, corn provides essential macronutrients like phosphorus for bone health, kidney function, and growth, and magnesium for heart rhythm regulation. Regular consumption of corn can also help protect against cardiovascular illnesses, diabetes, and hypertension by lowering LDL cholesterol. Its comprehensive nutritional profile, including carbohydrates, lipids, proteins, and various vitamins and minerals, contributes to its reputation as a valuable "poor man's nutritional cereal" that can benefit both health and food preparation (Kumar & Jhariya, 2013; Murdia et al., 2016; Siyuan et al., 2018; Alvarenga et al., 2021).

ROLE OF SOIL FERTILITY IN HYBRID WHITE CORN GROWTH

Acidic Soil Prevalence and Location

Acidic soils are prevalent across vast regions of Asia, particularly in southern China, Southeast Asia, and parts of India, such as Kuttanad. These areas also include coastal zones characterized by acid sulfate soils, which present additional challenges for agriculture (Hicks et al., 2008; Bhuyan et al., 2019; Rohith et al., 2024). Certain regions, including southern China, Burma, Hainan, Laos, Thailand, Vietnam, and the Western Ghats of India, are especially vulnerable to rapid soil acidification over the next 0 to 50 years. This vulnerability is driven by site-specific environmental factors and management practices that accelerate acidification processes (Hicks et al., 2008).

The effects of soil acidity on corn production and soil chemistry are substantial. When soil pH drops below 5.5, toxic concentrations of aluminium (Al^{3+}), iron (Fe^{3+}), and manganese (Mn^{2+}) can accumulate, severely stunting corn growth (Islam et al., 2021; Bhuyan et al., 2019). Moreover, the availability of essential nutrients such as phosphorus (P), calcium (Ca), magnesium (Mg), molybdenum (Mo), boron (B), and zinc (Zn) is significantly reduced, limiting plant development and yield potential (Havlin et al., 2016). Acidic conditions also diminish microbial activity, induce proton rhizotoxicity, disrupt membrane integrity and metabolic functions, increase reactive oxygen species (ROS) production, and impair water uptake, all of which negatively impact crop performance (Bhuyan et al., 2019). These challenges are further exacerbated by the continuous and unmanaged use of inorganic fertilizers, which intensifies soil acidification over time (Sulaeman et al., 2017).

Nutrient Imbalances and Amelioration Strategies

Soil nutrient imbalances are a major limiting factor in hybrid white corn production, particularly in acid-prone environments where nutrient availability and uptake are often compromised. One key interaction involves the calcium-to-magnesium (Ca:Mg) ratio, which, when imbalanced, can inhibit magnesium uptake and consequently affect the overall nutritional status of corn (Carlos Medeiros et al., 2008). Deficiencies in primary macronutrients such as nitrogen (N), phosphorus (P), and potassium (K) directly reduce maize yields, with phosphorus deficiency alone accounting for an estimated 10–15% loss in productivity (Fao, 2018; Shenoy & Kalagudi, 2005; Banaj et al., 2006). However, over-application of phosphorus fertilizers can lead to environmental degradation and induce micronutrient deficiencies without commensurate yield benefits (Bai et al., 2013; Glibert, 2017; Le et al., 2010; Cakmak, 2002; Stein, 2010). Furthermore, complementary agronomic factors—such as plant density, magnesium supply, and sulphur nutrition—play a critical role in enhancing nitrogen use efficiency and improving overall maize output (Gaj et al., 2020; Huang et al., 2010).

These nutrient-related challenges are compounded by ongoing soil acidification, which continues to intensify due to both natural processes and anthropogenic activities, including unsustainable fertilizer practices and deforestation. Left unmanaged, acidification poses a serious threat to long-term agricultural productivity (Rossel & McBratney, 2001). As such, a variety of soil amelioration practices have been developed and tested for effectiveness across acidic soil conditions. Among the most established is liming, particularly with materials such as shell lime or dolomitic lime, which effectively neutralize soil acidity across different textures. These practices are typically informed by assessments of soil chemistry, pH buffering capacity, and base saturation thresholds (Abdi, 2024; Soares-Wenneck et al., 2021).

More sustainable and integrative approaches involve the combined use of lime with organic amendments such as rice husk ash, green manures, and biochar. These combinations not only address pH correction but also enhance the nutrient profile of the soil over the long term (Rohit et al., 2024). Organic amendments—including poultry manure, cow dung, and compost—are particularly valuable for improving soil fertility by enhancing buffering capacity, increasing nutrient availability, and mitigating toxicities associated with excess iron (Fe) and aluminium (Al) (Islam et al., 2021; Banik et al., 2006; Siavoshi et al., 2011; Swain et al., 2012; Nweke & Nsoanya, 2015; Kobierski et al., 2017). The regular incorporation of well-decomposed organic matter stabilizes soil pH and improves phosphorus availability, both of which are critical in acidic soils. Consequently, integrated management strategies that combine lime with both organic and inorganic fertilizers are increasingly recommended for ensuring sustained soil productivity and crop yield under acid soil conditions (Islam et al., 2021).

Central to all these practices is the importance of soil organic matter (SOM), which plays a vital role in maintaining long-term fertility. SOM regulates biological activity, supports microbial communities, and enhances nutrient cycling efficiency, making it essential for the resilience of agroecosystems (Banik et al., 2006). Organic manures, as a key source of SOM, contribute not only to the chemical improvement of soil but also to its physical structure and biological functionality, which are all critical for the optimal growth of hybrid white corn and other crops.

DOLOMITIC LIME IN CORN PRODUCTION

Mechanisms of Action

The growth and productivity of maize in acidic tropical soils are significantly constrained by a combination of low pH, toxic levels of aluminium (Al) and manganese (Mn), and deficiencies in essential nutrients such as calcium (Ca), magnesium (Mg), and phosphorus (P). These chemical imbalances impair root development, hinder nutrient uptake, and drastically reduce maize yields if not corrected (Shamshuddin & Fauziah, 2010; Rabileh et al., 2015). Maize performs optimally in soils with a pH range of 6 to 8; outside this range—especially under strongly acidic conditions—yield responses to fertilizer inputs are often minimal unless liming is applied first (Labios et al., 2016). Thus, addressing soil acidity is a prerequisite for the effective utilization of added nutrients and the realization of potential yield gains.

Dolomitic lime serves as a multifaceted amendment by chemically neutralizing soil acidity through the release of hydroxyl (OH^-) and bicarbonate (HCO_3^-) ions from carbonate minerals such as calcite ($CaCO_3$) and dolomite ($CaCO_3$–$MgCO_3$). These reactions reduce the concentration of hydrogen ions (H^+) in the soil, thereby elevating pH and lowering exchangeable acidity as well as toxic Al and Mn levels (Abdi, 2024; Dawid & Hailu, 2017; Islam et al., 2021). In addition to these chemical effects, dolomitic lime enhances soil fertility by increasing the availability of phosphorus, cation exchange capacity (CEC), exchangeable base cations (Ca^{2+}, Mg^{2+}, K^+, Na^+), total nitrogen, and organic carbon while also reducing nutrient leaching and aluminium saturation (Abdi, 2024). Physically, lime application improves soil structure by promoting particle aggregation, decreasing bulk density, and increasing porosity—conditions conducive to healthy root growth and water retention. Its dual role as a source of both calcium and magnesium makes dolomitic lime especially beneficial for plant nutrition.

Liming also has profound implications for biological activity in soils. An elevated pH environment supports greater microbial proliferation and enzymatic activity, which accelerate the decomposition and mineralization of organic residues and animal manures, thereby releasing nutrients in plant-available forms (Penn & Camberato, 2019; Aye et al., 2016). These improved conditions alleviate deficiencies in other nutrients, particularly nitrogen, and support a more balanced nutrient profile (Liao et al., 2018; Liao et al., 2020; Halim, 2014). Furthermore, as soil pH increases, phosphorus bound to aluminium and iron (hydr)oxides is liberated, substantially enhancing phosphorus availability—an essential improvement for maize growth in acidic soils (Barrow, 2017).

From an agronomic perspective, the long-term application of lime has been shown to result in sustained improvements in soil fertility, maize productivity, and grain quality (Abdi, 2024). Empirical evidence strongly supports that lime, when applied in combination with chemical fertilizers, significantly outperforms the use of fertilizers alone in acidic soils (Labios et al., 2016; Dawid & Hailu, 2017). Indeed, proper liming is widely recognized as a foundational strategy for unlocking the full potential of added nutrients and achieving optimum yields in acid-affected environments (Shamshuddin et al., 2011; Abdi, 2024). Mechanistically, calcium ions from lime induce flocculation and cementation of soil particles, enhancing short-term physical soil structure (Abdi, 2024). Concurrently, the precipitation of toxic aluminum into inert Al-hydroxides as soil pH increases protects maize root systems from injury (Rabileh et al., 2015). Dolomitic lime also mitigates manganese toxicity by reducing Mn^{2+} concentrations, further supporting root function and overall plant health (Rabileh et al., 2015). These interconnected chemical, biological, and physical mechanisms collectively explain the pivotal role of dolomitic lime in revitalizing acidic soils and enhancing hybrid white corn productivity.

Effects on Hybrid White Corn Growth and Yield

Dolomitic lime has gained widespread adoption in several Asian countries for ameliorating soil acidity in hybrid white corn cultivation systems. In Bangladesh, its application is a common practice to address pH-related constraints (Islam et al., 2021). Similarly, in Japan, dolomite is extensively used to neutralize acidic soils, although it typically reduces the soil calcium-to-magnesium (Ca/Mg) ratio due to its 1:1

composition of Ca and Mg (Takamoto et al., 2021; Yang et al, 2024). Across various Asian regions, the application of dolomite has been shown to effectively increase soil pH, reduce aluminium (Al) toxicity, and enhance the availability of essential nutrients such as calcium, magnesium, and potassium (Kasno et al., 2023; Shamshuddin et al., 2011; Wang et al., 2006). Recommended application rates—generally around 2 tons per hectare—have proven sufficient to raise soil pH to near-neutral levels (~5.0), decrease Al and manganese (Mn) concentrations below critical thresholds, and improve cation exchange capacity (Chairiyah et al., 2021; Rabileh et al., 2015). These chemical improvements are not merely short-lived; the residual effects of dolomite can extend across three to six cropping seasons, depending on application rates and soil conditions (Wang et al., 2006).

Agronomically, dolomite enhances maize performance by increasing the availability of Ca and Mg, thus improving plant height, biomass accumulation, and grain yield (P et al., 2024; Rahman et al., 2005). Empirical findings show yield increases ranging from 10.8% to as high as 48.6%, contingent on lime rates and soil types (Wang et al., 2006). Moreover, combining 1 to 2 tons per hectare of dolomite with organic amendments such as poultry manure or farmyard manure (FYM) results in significantly improved maize productivity by optimizing both acidity correction and nutrient uptake (Sultana et al., 2019). In some cases, lime-treated plots have nearly doubled maize yields compared to untreated controls (Rabileh et al., 2013; Chairiyah et al., 2021). Higher application rates, up to 5–10 tons per hectare, continue to improve soil pH, increase exchangeable bases, and elevate soil total carbon and nitrogen, thereby enhancing overall crop productivity (Claoston et al., 2013).

Beyond its immediate yield effects, dolomite plays an important role in nutrient interactions and overall soil health. It supplies critical Ca and Mg, which influence the uptake of other cations such as potassium (K) due to ionic competition in the soil solution (Brady et al., 2008). More importantly, dolomite effectively reduces the toxic activities of Al^{3+} and Mn^{2+}, thereby alleviating metal toxicity stress on maize roots and improving plant vigor (Shamshuddin et al., 2011; Rabileh et al., 2015). These improvements in soil chemistry also led to higher nutrient availability, greater cation exchange capacity, and enhanced microbial activity, all of which contribute to favorable conditions for maize growth and development (P et al., 2024).

Alternative and complementary soil amendments such as rice husk ash, gypsum, phosphogypsum, and calcium magnesium silicates offer similar benefits by increasing soil pH, supplying nutrients, and mitigating metal toxicities (P et al., 2024). Moreover, co-application of lime with organic manure and mineral fertilizers further enhances maize yield and sustains soil fertility over the long term (Sultana et al., 2019). However, application strategies must be carefully calibrated: while an optimum dolomite dosage of about 2 tons per hectare is generally effective, under-application may leave acidity-related issues unresolved, whereas over-application could lead to nutrient imbalances or secondary deficiencies (Shamshuddin et al., 2011; Chairiyah et al., 2021). Therefore, lime management should be tailored to local soil conditions and types to maximize agronomic benefits, particularly in hybrid white corn production systems across acid-prone regions (Islam et al., 2021).

Application Methods and Rates of Dolomitic Lime in Southeast Asia

Dolomitic lime is commonly applied in agricultural soils through surface broadcasting followed by incorporation to enhance soil pH and reduce acidity. The depth of incorporation plays a critical role in the effectiveness of liming; studies from Malaysia, Indonesia, and other Southeast Asian countries indicate that incorporation depths typically range between 15 to 30 cm, with most research favoring 20 to 30 cm for optimal results (Shamshuddin et al., 2009). Proper incorporation ensures intimate contact between lime particles and acidic soil fractions, allowing for neutralization of hydrogen (H^+) and exchangeable aluminium (Al^{3+}) ions, which are major contributors to soil acidity (Chaney, 2012). For example, research in Malaysia showed that applying dolomitic limestone at 2 tons per hectare (t ha^{-1}) and incorporating it to 15 cm depth effectively raised soil pH to about 5 and reduced exchangeable aluminium to less than 1 cmol kg^{-1} of soil (Rabileh et al., 2015). Similarly, studies in Indonesia demonstrated that a 3 t ha^{-1} application of dolomite significantly increased soil pH to the range of 5.96 to 6.09, resulting in improved rice growth and yield (Hartatik et al., 2023).

The timing and frequency of lime application are also vital for achieving long-term soil improvements. Evidence from China's rice cultivation systems highlights that the massive quicklime method, with application rates ranging from 1,500 to 2,250 kg ha^{-1} for clay soils and 2,250 to 3,000 kg ha^{-1} for sandy soils, yields optimal outcomes (Zhou, 2022). The effects of dolomitic lime tend to be persistent; when applied either at full or divided rates on the soil surface, it continues to ameliorate soil acidity and increase calcium availability over time (Mahmud & Chong, 2022).

Application rates of dolomitic lime vary across different soil types and acidity levels in Southeast Asia but generally fall within the range of 2 to 6 t ha^{-1}. In Malaysia, rates between 2 and 4 t ha^{-1} are recommended for Ultisols, with 2 t ha^{-1} being standard for maize cultivation (Rabileh et al., 2015). Indonesia recommends 3 to 4 t ha^{-1} for acid sulfate soils and up to 6 t ha^{-1} for soils exhibiting severe acidity (Hartatik et al., 2023; Sulaeman et al., 2024). In Chinese paddy fields, lime application rates typically range from 1.5 to 3 t ha^{-1}, with higher amounts advised for sandy soils to achieve sufficient neutralization (Zhou, 2022). These recommended rates, coupled with appropriate incorporation depth and timing, are essential to maximize the benefits of dolomitic lime in improving soil fertility and crop productivity across diverse Southeast Asian agroecosystems.

MAGNESIUM'S PHYSIOLOGICAL FUNCTIONS IN PLANTS

Role in Photosynthesis and Enzyme Activation

Magnesium (Mg) plays a central role in plant physiology, particularly in photosynthesis and enzymatic processes essential for growth and development. As the core atom in chlorophyll molecules, Mg is directly responsible for capturing light energy, with approximately 15 to 35% of the magnesium absorbed by plants incorporated into chlorophyll structures, thereby supporting efficient light capture during photosynthesis (Ishfaq et al., 2022). Beyond its structural function, Mg is indispensable for photosynthetic carbon fixation. It acts as a critical cofactor for ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco), the key enzyme that fixes atmospheric CO_2, as well as ATP synthase and numerous other enzymes involved in carbohydrate metabolism (Ishfaq et al., 2022; Ahmed et al., 2023; Jaghdani et al., 2021).

Furthermore, magnesium activates over 300 enzymes including kinases, RNA polymerases, ATPases, phosphatases, and those essential for DNA and RNA synthesis, thereby supporting vital processes such as protein synthesis, nucleic acid formation, and energy transfer within plant cells (Ahmed et al., 2023). Magnesium also facilitates nutrient transport by aiding in the movement of photoassimilates like sucrose and plays a key role in maintaining cation balance and proper nutrient uptake (Ahmed et al., 2023). In essence, magnesium is fundamental not only for energy production through photosynthesis but also as a biochemical catalyst that drives plant growth, metabolism, and resilience (Ishfaq et al., 2022; Ahmed et al., 2023).

Effect on Hybrid White Corn Yield and Quality

Field studies consistently demonstrate that magnesium supplementation, particularly in acidic soils where Mg deficiency is common, significantly enhances corn productivity. For example, foliar application of 4% magnesium sulfate heptahydrate ($MgSO_4 \cdot 7H_2O$) in multi-season trials resulted in notable increases in sweet corn fresh ear yield, ear weight, number of grains per ear, and overall grain weight. In hybrid maize systems, magnesium not only boosts yield but also improves the uptake of key nutrients such as nitrogen, potassium, and calcium, while supporting chlorophyll health as indicated by higher SPAD values. This nutrient's availability is especially critical in high-density plantings where competition intensifies, making hybrids more sensitive to Mg deficiencies (Ye et al., 2025).

Beyond quantity, magnesium fertilization positively influences grain quality by increasing carbohydrate accumulation—including sucrose, fructose, and glucose—in kernels, which enhances grain filling and can improve quality attributes. Research across various maize hybrids further confirms that elevated tissue magnesium correlates with better physiological health, greater drought tolerance, and enhanced nutrient use efficiency, underscoring magnesium's essential role in sustaining both yield and crop resilience (Bojtor, 2022; Ye et al., 2025).

Recommended Magnesium Fertilization Practices

Magnesium fertilization in crop production can be effectively managed through both soil and foliar applications, each with distinct advantages depending on soil conditions and crop needs. Soil application of magnesium is commonly achieved using dolomitic limestone, which serves as a standard magnesium fertilizer while also correcting soil acidity. This method typically involves broadcasting and incorporating dolomitic lime before planting—often during the fall or prior to the wet season—and is especially recommended for acidic soils with pH levels below 6 where natural magnesium availability is limited (Bender et al., 2013; Oldham, 2019).

Application rates should be guided by soil testing to address local lime and magnesium deficiencies accurately. Soils that are sandy or situated in regions with high rainfall require higher magnesium inputs due to leaching losses from the root zone (Kaiser, 2016). In contrast, foliar application of magnesium, commonly through 4% magnesium sulfate ($MgSO_4$) solutions delivering about 8.8 kg Mg per hectare in split applications, offers a rapid correction of deficiencies during critical growth stages or under high-density planting systems. This method bypasses soil-related nutrient antagonisms and provides quick nutrient uptake, making it particularly valuable during periods of rapid vegetative growth or erratic rainfall (Ye et al., 2025; Rodrigues et al., 2021).

Best management practices emphasize using soil and tissue testing results to determine the appropriate magnesium fertilization strategy. Dolomitic lime is preferred where both soil pH correction and magnesium supplementation are needed, integrating two essential soil amendments in one application (Oldham, 2019; Rodrigues et al., 2021). Foliar magnesium applications are advisable under intensive production conditions such as high-yield or high-density crops and during environmental stresses that limit root nutrient uptake. Additionally, combining magnesium fertilization with organic matter amendments can enhance nutrient availability and improve soil health, especially in nutrient-poor acidic soils (Zhang et al., 2021). Together, these approaches ensure optimized magnesium nutrition tailored to crop and site-specific requirements, supporting both soil health and plant productivity.

Table 2. Magnesium fertilizer type, application rate, timing and notable effects on corn

Fertilizer Type	Timing	Application Rate	Notable Effects
Dolomitic limestone	Pre-planting	Based on soil test	Corrects pH, supplies Ca+Mg (Bender et al., 2013)
MgSO~4~ foliar spray	At key stages	4% solution x 3 sprays	Boosts yield and quality (Ye et al., 2025)
Mg + organic amendments	Pre-planting	Combined with crop residue	Increases yield, improves N efficiency (Zhang et al., 2021)

Three magnesium fertilizer strategies for hybrid white corn are highlighted in Table 2 which further details the type of fertilizer, recommended application timing, application rate, and notable effects. Dolomitic limestone is recommended before planting and applied based on soil test results. It corrects soil pH and supplies both calcium and magnesium, which supports optimal corn growth. Magnesium sulfate ($MgSO_4$) foliar spray is applied at key crop growth stages. Using a 4% foliar solution in three applications, it helps boost both yield and grain quality. Magnesium combined with organic amendments is also added pre-planting, typically with crop residues. This strategy enhances yield and improves nitrogen use efficiency in the crop. Each approach aims to address magnesium nutrition and related soil fertility issues in hybrid corn, with the notable effects including improved yield, nutrient efficiency, and overall crop health.

ZINC AS AN ESSENTIAL MICRONUTRIENT FOR CORN GROWTH

Role in Plant Physiology

Zinc is a critical micronutrient in plant physiology, playing indispensable roles in protein synthesis, chlorophyll production, enzyme activation, and overall growth regulation. As a structural component and cofactor for approximately 60 enzymes, zinc supports protein synthesis and is essential for DNA and RNA synthesis, facilitating proper protein folding and maintaining the structural integrity of proteins (Mason, 2006; Patil et al., 2023). It is also vital for ribosome formation, making it a key player in the entire process of protein creation within plant tissues (Hamzah Saleem et al., 2022). Zinc's role extends to chlorophyll biosynthesis, where it influences photosynthesis and leaf development by regulating auxin (notably indoleacetic acid, IAA) production. These plant hormones impact leaf size, chlorophyll content, and early ear development in corn (Elshamly et al., 2024; Hacisalihoglu, 2020). Deficiency in zinc can result in lower chlorophyll levels, diminishing photosynthetic capacity and compromising plant health and productivity (Dasgupta et al., 2024). Moreover, zinc activates over 300 enzymes involved in DNA synthesis, carbohydrate metabolism, and hormone regulation, including dehydrogenases and carboxypeptidases critical to energy production and metabolic balance. It also contributes to the detoxification of free radicals, enhancing plant resilience through improved antioxidant defense (Mason, 2006; Hamzah Saleem et al., 2022; Patil et al., 2023). Additionally, zinc influences cell division and elongation, contributing to proper growth rates and morphological development in corn (Elshamly et al., 2024). However, these physiological benefits are hindered in zinc-deficient conditions, particularly in agricultural systems where soil characteristics—such as alkalinity, sandy textures, high phosphorus levels, or cold, wet spring conditions—limit zinc bioavailability (Butzen, 2011; Westfall & Bauder, 2011).

In hybrid white corn, zinc deficiency manifests through distinct visual symptoms and measurable physiological impairments. Common indicators include interveinal chlorosis, often seen as yellow or white striping on the youngest leaves, usually appearing as broad bands flanking the midrib. Affected plants often exhibit stunted growth due to shortened internodes, leading to a "rosetting" appearance, and in severe cases, necrotic tissue and wilting may occur. White or pale-yellow longitudinal bands are particularly evident in the lower portions of the plant (Butzen, 2011; Westfall & Bauder, 2011; Soltangheisi et al., 2014; Rieck-Hinz & Mallarino, 2021). The physiological consequences of zinc deficiency include reduced leaf size, lower photosynthetic efficiency, compromised pollen production, and decreased kernel set. These issues collectively contribute to yield losses, which may reach or exceed 10% under moderate to severe deficiency conditions. Hybrid corn, especially under high plant density or environmental stress, is especially vulnerable to such yield reductions (Liu et al., 2020; Suganya et al., 2020; Saboor et al., 2021). Addressing zinc deficiency through appropriate fertilization and soil management is thus vital for sustaining both yield performance and nutritional quality, particularly in regions prone to zinc-deficient soils (Hacisalihoglu, 2020; Prabha, 2024).

Zinc Fertilization and Corn Yield

A growing body of field research underscores the positive impact of zinc fertilization on corn productivity, particularly in addressing yield limitations in zinc-deficient soils. Soil application of zinc fertilizers has been shown to increase corn grain yields by approximately 4% to 17%, primarily through improvements in kernel number and weight, especially in the apical or “inferior” grain sections of the cob where grain development is often limited (Liu et al., 2020). These yield gains are attributed to enhanced biomass accumulation and nutrient partitioning to the upper ears. Notably, Liu and colleagues found that zinc application improved pollen viability during the tasselling stage, a critical reproductive phase for ensuring kernel set.

Essential zinc concentrations in the plant shoot tissues required for optimal pollen viability and kernel development were identified as 31.2 mg/kg and 35.6 mg/kg, respectively. Moreover, the 1,000-kernel weight of the inferior grains increased significantly under zinc treatment, reflecting improved sink strength and photosynthate allocation. In addition to soil application, foliar zinc application—particularly zinc sulfate at approximately 1.5 ppm—has also been effective in enhancing physiological parameters and hybrid corn yield under field conditions (Munirah, 2015). However, higher foliar rates beyond this threshold did not translate to further yield gains and even reduced leaf water content and photosynthetic efficiency, highlighting the need for precise dose management. Further improvements in corn performance have been observed through the integration of zinc seed priming and foliar spraying techniques. This combined approach, especially when timed to key growth stages, has been reported to significantly increase chlorophyll content, plant dry weight, and seed quality, indicating synergistic effects of multi-modal zinc delivery (Agustiansyah et al., 2024). Together, these findings affirm that strategic zinc management—through soil, foliar, or integrated methods—can meaningfully enhance the physiological health, reproductive success, and yield potential of hybrid corn.

Recommended Zinc Application Practices

Optimizing zinc uptake in hybrid white corn requires the strategic selection and timing of application methods tailored to specific soil conditions and crop growth stages. Recent research supports four primary approaches: starter fertilizer applied at planting, broadcast incorporation before planting, foliar application during late vegetative stages, and precision placement at seeding or near the root zone. Starter fertilizers enhance early seedling vigor and root development, particularly effective in zinc-deficient or cool soils. Broadcast incorporation allows for broader soil correction over time, providing a foundation for long-term zinc availability. Foliar applications, typically used during the late vegetative phase, offer rapid correction of deficiencies and promote chlorophyll synthesis and reproductive health. Precision placement ensures targeted zinc delivery to the root zone, increasing uptake efficiency—especially vital in acidic, calcareous, or sandy soils where zinc mobility is limited. These methods, when properly applied, support improved early growth, photosynthetic activity, kernel development, and overall productivity.

Table 3. Application method of zinc fertilizers, timing, recommendations and key benefits on hybrid white corn

Application Method	Timing	Rate/Notes	Key Benefits
Starter Fertilizer	At planting (2x2 band)	0.5–2.0 lbs Zn/acre (chelated or soluble salts)	Immediate root uptake, early vigor (Butzen, 2011; Sutradhar et al., 2016)
Broadcast + Incorporate	Pre-plant	Up to 10 lbs Zn/acre for multiple years	Suits long-term correction
Foliar Application	Late vegetative stages	0.5–1.0 lbs Zn/acre (e.g., $ZnSO_4$ solutions)	Rapid correction of deficiency (Munirah, 2015)
Precision Placement	At seeding, root-zone	Banded applications more efficient, less residual	High efficiency on calcareous/sandy soils (Butzen, 2011; Westfall & Bauder, 2011)

To ensure adequate zinc nutrition throughout the growing season, regular plant tissue testing is recommended, with optimal zinc concentrations during vegetative stages ranging between 40 and 80 ppm (Butzen, 2011). Furthermore, integrating zinc fertilization with other key nutrients such as nitrogen and sulfur has been shown to enhance overall micronutrient uptake and improve plant physiological performance (Elshamly et al., 2024; Capo et al., 2024). Adopting an integrated, site-specific zinc management strategy can help prevent deficiencies, maximize yield potential, and sustain soil fertility in hybrid white corn production systems.

SYNERGISTIC EFFECTS OF DOLOMITIC LIME, MAGNESIUM, AND ZINC

The integrated amendment strategy of dolomitic lime, supplemental magnesium, and zinc has a synergistic effect on crop productivity and soil health in acidic soils—particularly for corn. These amendments collectively enhance the nutrient environment, physiological functions, and resilience of corn, resulting in improved biomass, chlorophyll content, root architecture, and yields (Noulas et al., 2018; Islam, et al., 2021; Bossolani et al., 2021; Ahmed et al., 2023; Ocaña-Reyes et al., 2024). Published studies and field trials confirm the efficacy of these combined approaches in multiple acid soil contexts, underscoring their value as part of sustainable, science-based agronomic practices.

Table 4. Interaction effects between dolomitic lime, magnesium and zinc on hybrid white corn in various parameters and places

Parameter	Country of Origin	Implications on Hybrid White Corn	References
Soil pH Adjustment & Nutrient Availability	Bangladesh, Brazil	Dolomitic lime raises soil pH in acidic soils, reducing toxic aluminum and increasing bioavailability of zinc, calcium, and magnesium for corn roots, promoting better nutrient uptake and soil fertility. This improves root growth and plant resilience.	Islam et al. (2021), Bossolani et al. (2021)
Magnesium Supply	Bangladesh, Indonesia	Magnesium from dolomitic lime is crucial for chlorophyll formation and enzyme activation, enhancing photosynthesis and stress tolerance in corn. Applying dolomite enhances Mg	Islam et al. (2021), Ahmed et al. (2023), Kasno et al. (2023)

		availability in acidic soils, which improves plant health and increases yield.	
Zinc Uptake	Bangladesh, Ghana	Zinc is vital for enzyme activity and protein synthesis in corn. Acidic soil limits zinc availability; raising pH with dolomitic lime increases zinc bioavailability and uptake, which supports normal growth and improved productivity. Balanced fertilization with lime and Zn is recommended.	Islam et al. (2021), Agyin-Birikorang et al. (2022), Delfim et al. (2025), Noulas et al. (2018)
Synergistic Effect on Nutrient Uptake	Bangladesh, Brazil, Ghana	Combined dolomitic lime and zinc application optimizes root nutrient uptake by improving soil conditions and microbial activity. This synergy promotes better carbohydrate utilization and nitrogen retention, which enhances corn growth and yield performance significantly.	Bossolani et al. (2021), Islam et al. (2021), Agyin-Birikorang et al. (2022)
Plant Health and Stress Resilience	Bangladesh, Brazil	Enhanced Mg and Zn availability through dolomitic lime application improves chlorophyll content and antioxidative metabolism in corn, increasing drought tolerance and stress resistance, resulting in more stable yields under adverse conditions.	Ahmed et al. (2023), Bossolani et al. (2021)
Balanced Fertilization Recommendations	Ghana	Fertilizer programs for maize should include liming to raise soil pH and Zn supply to address micronutrient deficiencies together. The interaction between lime, Mg, and Zn can change from antagonistic to synergistic with proper management, significantly improving maize productivity.	Agyin-Birikorang et al. (2022), Wallace (1984)

Table 4 summarizes research findings on the interaction between dolomitic lime, magnesium, and zinc and their combined effects on hybrid white corn growth and productivity. It outlines how dolomitic lime improves acidic soil conditions by raising soil pH, which enhances nutrient availability—particularly magnesium and zinc essential for chlorophyll production, enzyme activation, and protein synthesis. The synergy among these nutrients promotes better root development, nutrient uptake, stress resilience, and yield stability in hybrid white corn. Additionally, this highlights the importance of balanced fertilization practices incorporating lime and zinc to optimize these interactions. These findings are drawn from studies conducted in countries including Bangladesh, Brazil, Ghana, Indonesia, and Poland, emphasizing both soil chemistry improvements and physiological benefits for maize cultivation.

Impact on Agronomic Parameters

Table 5. Impact of dolomitic lime, magnesium and zinc application on the agronomic parameters of hybrid white corn in various places

Parameter	Country of Origin	Implications on Hybrid White Corn	References
Biomass and Yield	Brazil, Peru / Latin America	Application of dolomitic lime significantly increases maize grain yield and total biomass, in some cases by 125–308%, especially when combined with magnesium and zinc amendments. Mg-enriched lime materials enhance dry matter accumulation and shoot biomass, promoting overall crop productivity on acidic soils.	Delfim et al. (2025), Ocaña-Reyes et al. (2024), Bossolani et al. (2021)
Chlorophyll Content	Brazil, Peru / Latin America	Mg as the central atom of chlorophyll increases leaf chlorophyll content. Dolomitic lime enhances soil pH, reducing physiological stress and supporting pigment synthesis, resulting in greener, more productive leaves.	Bossolani et al. (2021), Ocaña-Reyes et al. (2024)

Root Development	Brazil, Bangladesh	Dolomitic lime improves root growth by alleviating soil acidity, allowing deeper root penetration and better nutrient and water access. Magnesium enhances root vigor, while zinc supports lateral root formation and elongation, collectively improving nutrient uptake efficiency.	Bossolani et al. (2021), Islam et al. (2021), Noulas et al. (2018)
Overall Yield	Bangladesh, Brazil, Peru / Latin America	Combined application of dolomitic lime, magnesium, and zinc leads to significant increases in grain yield through improved nutrient availability, photosynthetic capacity, and root system development, contributing to more stable and sustainable production under acidic soil conditions.	Islam et al. (2021), Bossolani et al. (2021), Ocaña-Reyes et al. (2024)

Extensive field and pot trials conducted in Asia and other regions with acidic tropical soils have demonstrated the substantial agronomic and physiological benefits of liming, particularly with dolomitic lime, and its synergistic use with zinc fertilizers in maize production (Table 5). Long-term liming trials involving surface-applied dolomitic lime and phosphogypsum in maize systems have shown marked improvements in plant health and yield. These include increased root biomass and penetration, elevated chlorophyll content, improved grain filling, and enhanced nutrient uptake, particularly of magnesium (Mg) and calcium (Ca), ultimately resulting in significantly higher yields (Bossolani et al., 2021). Similarly, comparative studies on forage corn using dolomite and lime amendments reported notable improvements in soil chemical properties and crop productivity, with the most pronounced effects observed when Mg and Ca deficiencies were concurrently corrected (Ocaña-Reyes et al., 2024). Pot experiments using coarse dolomite further confirm its long-lasting, slow-release capacity to boost Mg and Ca assimilation, reinforcing the sustained value of dolomitic lime for improving soil fertility and crop nutrition in acidic environments (Litvinovich et al., 2023).

In maize-specific contexts, long-term liming has also been linked to enhanced leaf pigment concentrations, increased antioxidative enzyme activity, and improved stress tolerance, such as during drought episodes—benefits attributable to more balanced nutrient availability and improved root zone conditions (Bossolani et al., 2021). Moreover, integrated studies on acid soil management highlight the positive interaction between magnesium supplied through liming and zinc fertilization. Although not all studies focus solely on maize, consistent yield responses in cereals, including maize, have been observed when both Mg- and Zn-containing amendments are applied under acidic tropical soil conditions (Islam et al., 2021; Noulas et al., 2018). These findings underscore the critical importance of correcting multiple nutrient deficiencies simultaneously and tailoring soil fertility management strategies to the specific limitations of acidic soils for optimal crop productivity and resilience.

PRACTICAL IMPLICATIONS FOR CORN FARMING IN ASIA: RESEARCH-BASED INSIGHTS

Improving Soil Fertility and Productivity

Table 6. Role of dolomitic lime, magnesium and zinc in addressing soil acidity and nutrient deficiencies in various places

Parameter	Country of Origin	Implications on Soil Fertility and Productivity	References
Soil Acidity Correction	Philippines, China, South America, Asia	Dolomitic lime effectively raises soil pH in acidic soils, neutralizing toxic aluminum, and improving chemical conditions conducive to crop growth. This	Rollon et al. (2020), Abbas et al. (2024), Antonangelo et al. (2022), Fageria & Nascente

		neutralization reduces nutrient fixation and enhances nutrient availability.	(2014), Zhang et al. (2023), Ngoune Tandzi et al. (2018)
Calcium and Magnesium Supply	South America, Asia	Dolomitic lime provides both Ca and Mg, critical for cell wall integrity, enzyme activity, and photosynthesis. Mg deficiency is common in weathered acidic soils; dolomitic lime supplies Mg which enhances chlorophyll synthesis and improves plant physiological functions.	Abbas et al. (2024), Bekker & Yapa (1994), Antonangelo et al. (2022), Fageria & Nascente (2014)
Zinc Availability and Uptake	Asia, Pacific Region	Acidic soils limit zinc availability, impairing enzyme function and protein synthesis. Liming raises soil pH, increasing Zn bioavailability. Co-application of Zn with lime prevents yield losses, enhances root development, and improves kernel set in maize.	Bekker & Yapa (1994), Abbas et al. (2024), Grasses (2004)
Improvement in Nutrient Cycling and Soil Microbial Activity	Philippines, Brazil	Liming along with Mg and Zn amendments promotes a better soil microbial environment by alleviating acidity and nutrient imbalances. This enhances nutrient cycling, organic matter decomposition, and active fractions of soil carbon, improving overall soil fertility.	Rollon et al. (2020), Abbas et al. (2024), Antonangelo et al. (2022)
Enhanced Biomass and Nutrient Uptake	Philippines, China	Application of dolomitic lime combined with Mg and Zn amendments increases maize biomass and nutrient uptake significantly, reflecting improved soil fertility status which supports plant growth and productivity under acidic soil conditions.	Rollon et al. (2020), Abbas et al. (2024)
Prevention of Yield Losses Due to Deficiencies	Asia, Pacific Region	Soils with low pH and deficiencies in Mg and Zn cause significant yield reductions. Integrated management including dolomitic lime and micronutrients maintenance stabilizes and improves crop yields through better soil fertility management.	Bekker & Yapa (1994), Abbas et al. (2024), Ngoune Tandzi et al. (2018)

Table 6 synthesizes findings on how dolomitic lime, magnesium, and zinc applications improve soil fertility and productivity, particularly in acidic and nutrient-deficient soils predominant in Asia, the Pacific region, and South America. Dolomitic lime plays a central role in correcting soil acidity and supplying calcium and magnesium, which are essential for plant physiological processes and soil chemical balance. Increasing soil pH through liming enhances zinc availability, crucial for enzyme activity and growth, which zinc deficiency often limits in acidic soils.

Additionally, these amendments foster improved nutrient cycling and microbial activity that sustain long-term soil health. The combined effect of these nutrients results in increased biomass production, nutrient uptake, and yield improvement in maize grown under challenging acidic conditions. The table highlights region-specific evidence demonstrating the importance of integrated soil fertility management using dolomitic lime and micronutrient supplementation to prevent yield losses and improve productivity sustainably.

Sustainable Practices for Long-Term Soil Health

Table 7 presents recommendations about the sustainable use of dolomitic lime, magnesium, and zinc soil amendments to promote long-term soil health. It emphasizes the importance of site-specific management through precise soil testing to tailor amendment rates appropriately, avoiding economic loss and environmental harm. The practice of integrated nutrient management—combining lime, Mg, Zn, and organic inputs—is highlighted as an effective strategy to simultaneously correct soil acidity, supply essential nutrients, and stimulate beneficial microbial activity. Moreover, the adoption of minimal soil disturbance techniques, such as minimal tillage, cover cropping, and organic residue retention, is endorsed for preserving soil structure and resilience, thereby complementing chemical amendments. Long-term field trials demonstrate that benefits from dolomitic lime and magnesium amendments maintain over several years, reducing the frequency of re-application and supporting sustainability in cropping systems. Lastly, the findings suggest caution to avoid excessive liming that may induce micronutrient imbalances, particularly zinc deficiencies, underscoring the necessity of balanced fertilization and ongoing soil nutrient monitoring.

Table 7. Application recommendations of dolomitic lime, magnesium and zinc for sustainable practices and long-term soil health

Parameter	Country of Origin	Implications and Recommendations for Sustainable Practices	References
Site-Specific Management	United States (North Carolina), South America, Asia	Accurate soil testing is essential to determine the proper rates of dolomitic lime, Mg, and Zn to avoid under- or over-application. Tailored amendments improve cost-effectiveness, prevent environmental risks, and optimize nutrient use efficiency for sustainable crop production.	Grasses (2004), Fageria & Nascente (2014), Khambalkar et al. (2025)
Integrated Nutrient Management	Asia, Brazil, South America	Combining dolomitic lime with magnesium, zinc, and organic amendments addresses multiple soil constraints simultaneously, improving nutrient cycling and supporting soil microbial health. This integrative approach enhances long-term soil fertility and crop productivity.	Abbas et al. (2024), Hossain et al. (2024), Khambalkar et al. (2025), Antonangelo et al. (2022)
Minimal Soil Disturbance	Asia (uplands and lowlands), ASEAN region	Adoption of minimal tillage, cover cropping, and retention of organic residues preserves soil structure, reduces soil erosion, and increases resilience. These practices complement lime and micronutrient use by maintaining favorable physical and biological soil properties over time.	Hossain et al. (2024), Anschell et al. (2021)
Long-Term Trials and Reapplication	Brazil	Long-term experiments show that lime and Mg-containing amendments improve soil chemical properties and fertility for multiple years, reducing the need for frequent application and supporting the sustainability of soil health improvements under no-till management.	Antonangelo et al. (2022)
Avoiding Nutrient Imbalances	Pacific Region (Pacific acid soils)	Excessive liming can cause micronutrient deficiencies, particularly zinc. Balanced liming combined with regular monitoring is necessary to sustain availability of Zn and other trace elements, preventing yield losses and long-term soil fertility decline.	Bekker & Yapa (1994)

Cost-Effectiveness of Using Dolomitic Lime, Magnesium, and Zinc

Recent field-based and modelling studies underscore the substantial agronomic and economic benefits of applying dolomitic lime in combination with mineral fertilizers and organic amendments on acidic soils. In maize cultivation, such integrated nutrient management strategies have resulted in yield increases of up to 30% relative to unfertilized control plots. These gains are attributed to improved soil pH, reduction in exchangeable aluminum, and enhanced nutrient bioavailability—particularly of calcium and magnesium within the crop rhizosphere. In trials involving various maize hybrids, some genotypes exhibited yield increments exceeding 7,000 kg ha^{-1} when dolomitic lime was co-applied with inorganic nutrients and manure (Zhang et al., 2023).

A growing body of evidence emphasizes the long-term economic viability of liming in acid-prone maize systems. Studies conducted in Asia and sub-Saharan Africa report favorable internal rates of return (IRR), typically ranging between 20% and 40%, even after accounting for the costs of lime procurement, transportation, and application (Zhang et al., 2023; Otieno et al., 2024). These analyses highlight the importance of strategic liming—optimizing rates and timing, rotating crops, and incorporating organic inputs—to maximize productivity and ensure sustainability. Yield responsiveness, lime price, and maize market dynamics are critical variables influencing profitability.

Dolomitic lime presents a dual-functionality advantage by simultaneously correcting soil acidity and supplying magnesium—rendering it more cost-efficient than the separate application of calcitic lime and magnesium-based fertilizers (Grasses, 2004; Khambalkar et al., 2025). Additionally, zinc fertilization—especially when delivered through starter applications or foliar sprays targeted at confirmed deficiency zones—has proven both agronomically effective and economically viable (Abbas et al., 2024).

Combining dolomitic lime and micronutrient fertilizers with organic amendments (e.g., compost, manure) and conservation agriculture practices has been shown to improve long-term soil fertility and reduce dependency on external inputs. These integrated strategies enhance soil organic carbon, improve nutrient retention, and reduce leaching losses, thereby lowering recurring input costs and bolstering system resilience (Hossain et al., 2024; Khambalkar et al., 2025).

CONCLUSION

This review has comprehensively examined the synergistic roles of dolomitic lime, magnesium, and zinc in enhancing hybrid white corn productivity in acid-prone soils across Asia. Guided by the objectives to assess their individual and combined effects on soil fertility, physiological functioning, and agronomic performance, the findings reveal that these amendments are not only critical in correcting soil acidity but are also instrumental in optimizing nutrient availability and plant health.

Dolomitic lime emerged as a foundational input for neutralizing toxic soil acidity, mitigating aluminium and manganese toxicities, and improving the overall chemical environment conducive to crop growth. Its dual role in supplying both calcium and magnesium make it uniquely valuable for correcting multiple soil deficiencies simultaneously. Magnesium, as a core component of chlorophyll and a cofactor in key enzymatic pathways, significantly enhances photosynthetic efficiency, carbon fixation, and biomass accumulation in hybrid corn. Zinc, often deficient in acidic soils, is vital for protein synthesis, enzymatic regulation, and reproductive success, and its bioavailability is greatly improved with liming interventions.

The review also confirms that the integrated application of dolomitic lime, Mg, and Zn leads to synergistic enhancements in root architecture, chlorophyll content, nutrient uptake, and grain yield. These improvements are particularly evident under field conditions characterized by low pH and micronutrient deficiencies, suggesting that a holistic nutrient management strategy is essential for sustainable intensification. Furthermore, long-term studies demonstrate that these amendments not only boost productivity but also contribute to improved soil health through enhanced microbial activity, organic matter stability, and nutrient cycling.

In practical terms, the adoption of site-specific, integrated nutrient management strategies involving dolomitic lime, magnesium, and zinc—complemented by organic inputs and conservation practices—can substantially improve the resilience and profitability of hybrid white corn systems in Asia. Future research should prioritize refining region-specific application rates, explore genotype-specific responses, and scale up farmer-level adoption through policy support and extension services. By aligning agronomic innovation with ecological sustainability, the combined use of dolomitic lime, magnesium, and zinc represents a scalable pathway toward achieving food security, soil health, and agricultural resilience in the region.

Declaration by Authors

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