Research Review Article

Current Horticulture 14(3): 19-24, July–September 2026

DOI: 10.5958/2455-7560.2026.00033.6

Received: 24 June 2026; Revised: 16 July 2026: Accepted: 03 September 2026

Enhancing nutrient-use efficiency and productivity in tomato (*Solanum lycopersicum*) using blended fertilizers: a review

Desalegn Negasa*

Department of Plant Science, Wollega University, Shambu, Ethiopia

Abstract

Tomato (*Solanum lycopersicum* L.) is a globally vital vegetable crop, yet optimizing its genetic potential for yield and quality is frequently hindered by suboptimal soil fertility management. Continuous blanket application of straight macronutrient fertilizers often results in imbalanced plant nutrition by contributing to secondary and micronutrient deficiencies.Multi-nutrient blended fertilizers incorporating primary, secondary, and micronutrients have emerged as a critical innovation to deliver a balanced nutrient profile. However, a comprehensive synthesis of their interactive mechanisms, optimal formulations, and agro-ecological performance remains fragmented. A systematic narrative review framework was executed by querying dominant digital databases (including Web of Science, Scopus, Science Direct, and Google Scholar) for peer-reviewed field, greenhouse, and meta-analysis studies spanning from 2000 through mid-2026. Information on tomato growth, yield components, nutrient use efficiency indices, and environmental impacts was extracted and synthesized qualitatively. The synthesized literature reveals that tailored multi-nutrient blends systematically resolve physiological bottlenecks, expanding leaf area index by 18% to 34% over conventional inputs. By optimizing floral development, reducing fruit abortion rates via boron (B) synergies, and mitigating blossom end rot through calcium (Ca) interactions, multi-nutrient blending drives absolute marketable fruit yield increases ranging from 15% to 42%. Furthermore, balanced fertilization promotes enhanced lateral root architecture and enhances root nutrient uptake through improved root growth and physiological activity, elevating agronomic and recovery efficiency while reducing nitrous oxide (N2O emissions and leaching. Transitioning to multi-nutrient blending technologies is a highly viable strategy to simultaneously maximize tomato productivity, improve human dietary health through trace element bio fortification, and reduce environmental footprints. Future research should prioritize long-term soil residual chemistry, nano-formulations, and targeted organo-mineral combinations.

Key words: Balanced nutrition, Micronutrient enrichment, Marketable yield, Nutrient uptake.

Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated and economically important vegetable crops globally, serving as a vital source of vitamins, minerals, and essential antioxidants like lycopene (Buajaila *et al.,* 2022; Gao *et al.,* 2023). Despite its high market demand and dietary significance, realizing the genetic yield and quality potential of tomato remains a major challenge for growers. A primary limiting factor is suboptimal soil fertility management. Traditionally, blanket applications of straight, highly soluble chemical fertilizers—primarily nitrogen (N), phosphorus (P), and potassium (K) have been the standard practice in intensive agriculture (Gao *et al.,* 2023). However, this imbalanced fertilization strategy often fails to match crop nutrient demand in terms of timing and quantity. (Rahman *et al.,* 2021). Over time, it leads to severe secondary and micronutrient deficiencies, accelerated soil degradation, and sharply declining nutrient use efficiency (NUE) due to substantial nutrient losses via leaching, volatilization, or environmental fixed-states (Gao *et al.,* 2023; Rahman *et al.,* 2021).

In response to these soil constraints, multi-nutrient blended fertilizers have emerged as a pivotal innovation in modern sustainable agriculture. By combining primary (N, P, K), secondary (such as sulfur, calcium, and magnesium), and micronutrients (such as boron, zinc, copper, and iron) into a single formulation, these blends aim to deliver a balanced, synchronous nutrient profile tailored to specific crop requirements and soil types (Jing, 2025; Stoeva, 2026). Balanced nutrition is well-documented to stimulate robust vegetative growth, increase plant height and leaf area index, enhance photosynthetic pigment synthesis, and improve yield components in tomatoes (Jing, 2025; Rahman *et al.,* 2021). Furthermore, synchronizing multi-element delivery minimizes internal plant nutrient antagonism and improves overall root uptake capacity, which significantly elevates the partial productivity of fertilizers and boosts long-term NUE (Liu *et al.,* 2024; White and Broadley, 2009).

The Knowledge Gap: While the broad agronomic benefits of macronutrient application are well-established, there is a critical shortage of synthesized data regarding how complex multi-nutrient blended formulations interact under varying agro-ecological conditions to influence the distinct physiological growth stages and overall fruit quality of *Solanum lycopersicum* L. (Gao *et al.,* 2023; Jing, 2025). Most existing literature focuses heavily on isolated, straight nutrient responses or localized

***Corresponding author :** gemechubekam@gmail.com

organic-chemical combinations (Buajaila *et al.,* 2022; Gao *et al.,* 2023). This leaves the systematic synergistic mechanisms, optimal multi-element blending ratios, and the balancing point between micronutrient enrichment and potential yield reductions poorly understood and fragmented across the scientific community.

Consequently, a comprehensive synthesis of current research is urgently needed to guide future agronomic recommendations and custom fertilizer manufacturing. Therefore, the objective of this review is to evaluate the effects of multi-nutrient blended fertilizers on the growth parameters, yield attributes, and nutrient use efficiency of tomato (*Solanum lycopersicum* L.), highlighting current technical advancements, identifying critical research gaps, and outlining strategies for optimized, sustainable production.

Review approach

This study utilizes a systematic narrative review approach to evaluate, synthesize, and interpret existing scientific literature on the impacts of multi-nutrient blended fertilizers on agronomic performance of tomato. Rather than analyzing isolated nutrient elements, this approach allows for the integration of complex agronomic data across diverse soil profiles, macro-micronutrient blending formulations, and agro-ecological zones (Akinyemi *et al.,* 2023; Geremew *et al.,* 2026). By structuring the review process systematically, the analysis objectively traces the physiological mechanisms through which balanced formulations influence tomato vegetative growth, fruit yield components, and nutrient use efficiency (NUE) metrics, while thereby reducing potential reviewer bias (Gusenbauer and Haddaway, 2020; Snyder, 2019).

Search strategy

A comprehensive, multi-database digital search was executed to identify peer-reviewed research articles, book chapters, and technical reports published from January 2000 through June 2026. The primary electronic databases searched included Web of Science, Scopus, ScienceDirect, and Google Scholar (Gusenbauer and Haddaway, 2020; Tondey *et al.*, 2025). The search string was constructed using strict Boolean operators (and, or) and specific keyword truncations to capture all relevant publications.

The standardized search string applied across the engines was:

("tomato" or "*Solanum lycopersicum*") and ("multi-nutrient blend*" or "blended fertilizer*" or "balanced nutrition" or "micronutrient enrichment") and ("growth" or "yield" or "fruit quality" or "nutrient- use efficiency" or "NUE")

To minimize missing data, the reference lists of all retrieved primary studies and relevant global agronomic surveys were manually screened via backward snowballing to discover additional high-impact historical literature (Page *et al.,* 2021).

Inclusion and exclusion criteria

To maintain high scientific rigor and avoid confounding variables, clear inclusion and exclusion boundaries were established prior to screening the literature database (Higgins *et al.,* 2019; Tondey *et al.,* 2025).

Criteria	Inclusion boundaries	Exclusion boundaries
Study type	Peer-reviewed experimental studies, multi-year field trials, greenhouse/pot experiments, and meta-analyses (Akinyemi *et al.,* 2023).	Editorials, opinion pieces, non-peer-reviewed popular media, and studies lacking clear statistical validation or ANOVA indicators.
Crop focus	Tomato (*Solanum lycopersicum* L.) commercial varieties (field-grown, greenhouse, or hydroponic coir/ substrates).	Intercropping systems where tomato specific nutrient uptake data could not be isolated from the companion crop.
Intervention	Blended formulations combining primary macronutrients (NPK) explicitly with secondary (Ca, Mg, S) or micronutrients (Zn, B, Fe, Cu).	Studies evaluating *only* individual straight fertilizers (e.g., urea or triple superphosphate alone) without a multi-nutrient blending context.
Outcome measures	Quantifiable metrics for vegetative growth, fruit yield components, or calculated nutrient use efficiency (NUE) metrics (Geremew *et al.,* 2026).	Studies evaluating solely sensory preferences or post-harvest shipping engineering without active crop agronomic data.

Data extraction and organization

Articles meeting the inclusion criteria underwent a standardized data extraction process using a centralized matrix protocol to ensure alignment across datasets (Page *et al.,* 2021). The following parameters were systematically extracted from each text:

Bibliographic information: Author(s), publication year, and geographical location of the study.

Experimental metadata: Trial environment (field, greenhouse, or hydroponics), soil physicochemical properties (initial pH, organic matter, baseline nutrient status), and tomato cultivar type (indeterminated vs. determinated).

Fertilizer characteristics: Exact multi-element nutrient composition, blending ratios, total application rates (kg/ha), and timing or delivery methods (e.g., basal application vs. split top-dressing).

Agronomic target metrics: Vegetative data (plant height, leaf area index, dry biomass), yield data (fruit number per plant, average fruit weight, total marketable yield), and specific NUE indices, including agronomic efficiency (AE), apparent recovery efficiency (ARE), and partial factor productivity (PFP) (Fixen *et al.,* 2015; Geremew *et al.,* 2026).

Data synthesis and interpretation

Due to the heterogeneous nature of the collected agronomic data—stemming from varied soil conditions, differing nutrient blend concentrations, and divergent local environments—a qualitative and narrative data synthesis was executed (Snyder, 2019). Data were grouped categorically based on primary agronomic outcomes: growth response, total crop yield, and nutrient uptake dynamics.

The interpretation focused on identifying core physiological patterns, such as the synergistic interactions between macronutrients and micronutrients (e.g. how zinc or boron presence influences nitrogen or phosphorus uptake via enzyme activation) (Fixen *et al.,* 2015). Conflicting findings in the literature were systematically evaluated by cross-referencing environmental confounding factors, such as soil pH or irrigation regimes (Geremew *et al.,* 2026). Finally, the synthesized data were contrasted against traditional straight fertilizer baselines to quantify the net percentage variations in yield and NUE offered by modern multi-nutrient blending technologies.

Limitations of conventional nutrient regimes

Historically, soil fertility strategies for tomato (*Solanum lycopersicum* L.) cultivation relied heavily on conventional, straight macronutrient regimes—most notably Diammonium Phosphate (DAP) and Urea (Gao *et al.,* 2023; Hailu *et al.,* 2025). While this standard practice delivers concentrated inputs of nitrogen (N) and phosphorus (P), decades of continuous application have has contributed to several agronomic constraints.

Conventional methods ignore the depletion of secondary macronutrients and critical micro-elements. This imbalance leads to widespread “hidden hunger” in intensive vegetable systems (Fisseha *et al.,* 2026; Mashamaite *et al.,* 2024). Furthermore, highly soluble straight fertilizers saturate the soil solution rapidly, exceeding the immediate uptake capacity of the tomato plant’s roots. This lack of synchronization triggers major nutrient loss pathways:

- Free nitrates (NO_3) leach quickly past the root zone.
- Ammonium (NH_4) undergoes rapid volatilization.
- Soluble orthophosphates (H_2PO_4) bind tightly to iron and aluminum oxides in acidic soils, locking them in an unavailable, fixed state (Fixen *et al.,* 2015; Wu *et al.,* 2024).

Consequently, conventional fertilization often results in diminishing returns, poor fruit quality, and low nutrient use efficiency (NUE).

Emergence of blended NPSBZn formulations

To resolve the limitations of traditional macro-only protocols, recent research has increasingly focused on multi-nutrient macro-micronutrient complexes. A prominent innovation in this space is **NPSBZn** fertilizer—a targeted blend containing tailored proportions of Nitrogen, Phosphorus, Sulfur (S), Boron (B), and Zinc (Zn) (Fisseha *et al.,* 2026; Hailu *et al.,* 2025).

This multi-nutrient formulation acts as a comprehensive nutritional package. It addresses widespread trace element deficiencies caused by intensive farming and continuous soil mining (Fisseha *et al.,* 2026; Tondey *et al.,* 2025). In these micro-enriched blends, the individual nutrients are bound together, preventing the chemical segregation common in physical field mixes. This ensures uniform nutrient distribution across the crop field, giving every plant simultaneous access to all five elements (Hailu *et al.,* 2025).

Effect of NPSBZn on yield and its components

Extensive field trials demonstrate that shifting from conventional NPK or DAP/Urea baselines to blended NPSBZn fertilizer significantly increases total tomato productivity, typically optimizing application rates between 150 kg/ha and 250 kg/ha depending on the cultivar and local soil properties (Fisseha *et al.,* 2026; Hailu *et al.,* 2025). This yield bump is driven by the synergistic impacts of the blended components on individual yield attributes:

- **Flower retention and fruit set percentage:** Omiting boron in conventional systems causes high flower abortion rates. The inclusion of boron (B) within the NPSBZn matrix improves pollen tube elongation and grain viability. This directly reduces floral drop, resulting in a higher number of fruit clusters per plant and an increased overall fruit set percentage (Hailu *et al.,* 2025; Stoeva, 2026).
- **Fruit structural dimensions and marketable size:** Zinc (Zn) plays a key role as a catalytic building block for indole-3-acetic acid (IAA). This up-regulates cell division and expansion during early fruit development. When applied via balanced blends, zinc increases average fruit length, fruit diameter, and individual fruit weight (Fisseha *et al.,* 2026; Rahman *et al.,* 2021).

- **Reduction in unmarketable yield:** The combination of sulfur (S) with trace micronutrients improves the uptake of primary macronutrients and secondary elements like calcium (Ca). This physiological balance lowers the incidence of blossom end rot and fruit cracking, increasing the volume of high-quality, marketable fruit (Gao *et al.,* 2023; Hailu *et al.,* 2025).

Recent field studies evaluating diverse tomato varieties (such as *Melka sholla*, *Gele lma*, and *Roma-VF*) show that optimizing NPSBZn blending strategies regularly produces high fruit yields, with top performances reaching 38.1 to 64.11 t/ha (Fisseha *et al.,* 2026; Research Gate, 2024). These results highlight the strong economic and agronomic value of replacing outdated, straight fertilizer inputs with balanced, crop-specific formulations.

Effect of multi-nutrient blended fertilizers on growth

The synthesis of reviewed literature consistently demonstrates that multi-nutrient blended fertilizers containing macro, secondary, and micronutrients prompt a significantly higher vegetative growth response in tomato compared to conventional straight fertilizers (e.g. urea or DAP alone). Key growth indicators such as plant height, leaf area index (LAI), and total dry biomass production showed uniform positive responses to balanced multi-nutrient inputs across varied trial environments (Geremew *et al.,* 2026; Jing, 2025).

The observed expansion in growth parameters is mechanically linked to the physiological synergies of balanced nutrition. While nitrogen serves as the structural foundation for amino acids and chlorophyll synthesis, its metabolic processing depends heavily on the presence of trace elements. For instance, zinc (Zn) serves as a catalytic precursor for tryptophan synthesis, which is the direct metabolic driver of the growth hormone indole-3-acetic acid (IAA). Additionally, boron (B) is structurally vital for cell wall pectin cross-linking, facilitating continuous cell division at apical meristems (Stoeva, 2026; White and Broadley, 2009).

When these micronutrients are omitted in imbalanced fertilization schemes, plants exhibit physiological bottlenecks, marked by stunted growth, fragile stems, and localized interveinal chlorosis. Recent meta-analyses confirm that integrating organic matrices—such as Black Soldier Fly (BSF) compost—with mineral multi-nutrient blends enhances biochemical mineralization, resulting in increased dry shoot biomass and raising the plant health index significantly above standard synthetic NPK inputs (Zaato, 2025). Synthesized data reveals that incorporating secondary elements like sulfur (S) alongside trace micronutrients expands tomato LAI by 18% to 34% compared to NPK-only controls, directly optimizing net carbon assimilation rates via increased light interception (Rahman *et al.,* 2021).

Yield and its components

Tomato fruit yield is a multi-component metric dictated by the number of flower clusters per plant, fruit set percentage, average fruit weight, and the overall ratio of marketable to unmarketable fruit. The literature shows that multi-nutrient blends significantly enhance these specific yield components, culminating in elevated total fruit yields per hectare (Buajaila *et al.,* 2022; Liu *et al.,* 2024).

The physiological mechanism behind this yield bump lies in the transition from vegetative to reproductive growth. As illustrated in the developmental stages above, fruit set and expansion require intense carbohydrate translocation from leaves to developing sinks. Boron plays an indispensable role in maintaining pollen grain viability and pollen tube elongation; when blended into baseline fertilizers, it decreases flower abortion rates and dramatically increases the total number of fruits set per individual vine (Stoeva, 2026). Furthermore, the inclusion of potassium (K) combined with calcium (Ca) in multi-nutrient blends minimizes the occurrence of blossom end rot—a physiological disorder stemming from localized calcium deficiencies during cell expansion—thereby driving up the marketable yield index (Gao *et al.,* 2023).

Recent field trials reveal that when macro-micronutrient complexes are blended with biochar or tailored bio-composts, tomato yield increases of up to 191.6% can be achieved over unfertilized controls, while simultaneously improving postharvest shelf-life, vitamin C concentration, and lycopene synthesis (Mashamaite *et al.,* 2024; Zaato, 2025). Across multiple reviewed field trials, complete multi-nutrient formulations achieved absolute marketable yield increases ranging from 15% to 42% over unblended check treatments (Geremew *et al.,* 2026; Rahman *et al.,* 2021).

Nutrient-use efficiency and physiological interactions

A central goal of agronomic blending is maximizing the partial factor productivity of applied elements. Traditional fertilization practices suffer from low efficiency because high volumes of straight macronutrients saturate the soil solution, leading to fixation or environmental loss. The integration of advanced multi-nutrient blends and stabilized compound fertilizers effectively mitigates these pathways, significantly improving agronomic efficiency (AE) and apparent recovery efficiency (ARE) while limiting ammonia (NH_3) volatilization and greenhouse gas emissions like N_2O (Fixen *et al.,* 2015; Wu *et al.,* 2024).

Fertilizer regime	Average Agronomic Efficiency (AEN, kg fruit/kg N)	Apparent Recovery Efficiency (AREP, %)	Primary Loss Pathways Mitigated
Straight NPK (conventional)	12.4 - 15.8	15\% - 22\%	High leaching, rapid P-fixation in acidic soils
Multi-nutrient blends (+S, Zn, B)	22.1 - 28.5	31\% - 44\%	Antagonism reduction, rootnetworkexpansion, lower volatilization

This elevated efficiency is driven by improvements in root morphology and physiological processes within the plant root system. Balanced nutrition induces greater root length density and lateral root branching, expanding the volumetric zone of soil exploration (White and Broadley, 2009). At a biochemical level, elements like zinc act as key structural components of carbonic anhydrase and various dehydrogenases, which indirectly up-regulate the active transport proteins responsible for nitrate (NO_3) and phosphate (H_2PO_4) uptake across root cell membranes (Rahman *et al.,* 2021).

Furthermore, by integrating nitrification or urease inhibitors within stable compound multi-nutrient blends, studies demonstrate a simultaneous reduction in environmental footprint—such as a 38.5% drop in N2 emissions while maximizing the synchronization between crop demand and soil nutrient availability (Wu *et al.,* 2024). By managing the release and proximity of multi-elements, blended fertilizers successfully circumvent localized nutrient antagonism—such as the competitive inhibition of phosphorus over zinc uptake—promoting instead a balanced consumption profile that improves fertilizer recovery rates (Fixen *et al.,* 2015; Jing, 2025).

Future research

While the short-term agronomic benefits of multi-nutrient blended formulations are clear, several critical gaps must still be addressed to guide future agricultural development:

- **Long-term soil dynamics and residual chemistry:** Most existing research relies on short-term, single-season field or greenhouse trials. Long-term, multi-year field experiments across diverse soil classifications are urgently needed to assess the cumulative effects of multi-nutrient blending on soil organic matter, microbial ecology, baseline nutrient build-up, and the long-term risk of heavy metal or micro-element toxicities.
- **Smart nano-formulations and nano-coatings:** Future research should prioritize developing and testing advanced nano-enabled multi-nutrient delivery systems (e.g., chitosan or polymer-coated nano-fertilizers). Investigating how these responsive materials synchronize multi-element release with the specific developmental growth stages of the tomato plant can help maximize NUE and minimize environmental losses.
- **Synergistic organo-mineral and biochar composites:** There is a critical need to systematically map the interactions between synthetic multi-nutrient mineral blends and organic matrices, such as biochar, Black Soldier Fly compost, and custom bio-fertilizers. Research should focus on finding the optimal ratios that maximize nutrient retention, boost carbon sequestration, and stimulate soil enzymes.
- **Genotype by environment by management (G * E) interactions:** Future studies must explore how modern determinate and indeterminate tomato cultivars react to specific nutrient blends under variable environmental stressors, such as drought, salinity, or extreme heat. This will allow for the development of dynamic, region-specific blending formulas rather than relying on broad, regional generalizations.
- **Economic viability and smallholder adoption dynamics:** To move these technologies from the lab to the field, comprehensive life-cycle cost-benefit analyses are required. Researchers should evaluate the economic returns of custom blending for smallholder vegetable production systems, identifying the socioeconomic barriers to adoption and formulating policy strategies to improve market access to premium blended fertilizers.

CONCLUSION

This comprehensive review demonstrates that moving away from conventional, imbalanced blanket applications of straight macronutrients (NPK) toward tailored, multi-nutrient blended fertilizers is an essential paradigm shift for sustainable tomato (*Solanum lycopersicum* L.) production. Synthesized data across diverse agro-ecological zones confirms that the precise integration of primary macronutrients with essential secondary elements (Ca, Mg, S) and trace micronutrients (Zn, B, Fe) effectively resolves localized hidden hungers and physiological bottlenecks. This balanced nutritional approach significantly improves tomato vegetative growth parameters, such as plant height and leaf area index, and enhances key yield components, resulting in marketable fruit yield increases ranging from 15% to 42%.

Crucially, multi-nutrient blending technologies improve nutrient use efficiency (NUE) by expanding root network architecture and stimulating biochemical transport pathways. This minimizes environmental losses through ammonia volatilization, greenhouse gas emissions (N_2O), and nutrient leaching. Ultimately, multi-nutrient blended fertilization represents an ecologically sound and agronomically viable strategy to optimize tomato productivity, bolster human dietary health via micronutrient bio fortification, and safeguard soil resource longevity

REFERENCES

Akinyemi, I. O., Ojeniyi, S. O., and Fasina, A. S. 2023. Methodological frameworks for systematic reviews in agricultural soil fertility management: A critique. *Journal of Soil Science and Plant Nutrition* **23** (2): 1411–25. https://doi.org/10.1007/s42729-023-01192-w.

Buajaila, F., Cowan, J. S., Inglis, D., Carpenter-Boggs, L., and Miles, C. 2022. Tomato growth, yield, and quality response to mixed chemical–organic fertilizers and grafting treatments in a high tunnel environment. *Canadian Journal of Plant Science* **10**2(1): 33–48. https://doi.org/10.1139/cjps-2020-0342.

Fisseha, K., [*et al.*] (2026). Effect of NPSZnB fertilizer on yield and horticultural traits of tomato (*Solanum lycopersicum* L.) varieties in Tanqua Milash District of Tigray. *Vegetable Science* **53**(1): 370–78.

Fixen, P., Brentrup, F., Bruulsema, T., Garcia, F., Lawrence, R., Mikkelsen, G., Ruston, M. and Snyder, C. 2015. Nutrient/fertilizer use efficiency: Measurement, current situation and trends. *In*: *Managing Nutrient Use Efficiency in Crop Production,* W. R. Stewart, W R (Ed.), pp. 1–38. International Plant Nutrition Institute.

Gao, F., Li, H., Mu, X., Gao, H., Zhang, Y., Li, R., Cao, K.and Ye, L. 2023. Effects of organic fertilizer application on tomato yield and quality: A meta-analysis. *Applied Sciences* **13**(4): 2184. https://doi.org/10.3390/app13042184.

Geremew, S., Tesfaye, A., and Tolossa, D. 2026. Current production status of tomato (*Solanum lycopersicum* L.) in Ethiopia: A comprehensive review. *Current Agronomy Research* **14**(3):210–28. https://doi.org/10.1016/j.car.2026.02.015.

Gusenbauer, M., and Haddaway, N. R. 2020. Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of 28 databases. *Research Synthesis Methods* **11**(2): 181–217. https://doi.org/10.1002/jrsm.1378.

Hailu, T. T., Wako, G., and Gobena, A. 2025. Effect of blended NPSBZn fertilizer rates on growth and quality of tomatoes (*Solanum lycopersicum* L.) varieties at Hawassa, Southern Ethiopia. *Journal of Agricultural Research, Pesticides and Bio fertilizers* **6**(2): 291–304.

Higgins, J. P. T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., and Welch, V. A. (Eds). (2019). *Cochrane handbook for systematic reviews of interventions* (2nd edn). Wiley-Blackwell.

Jing, L. 2025. Optimum N:P:K ratio of fertilization enhances tomato yield and quality under brackish water irrigation. *Plants* **14**(16): 2496. https://doi.org/10.3390/plants14162496.

Liu, S., Qiang, X., Liu, H., Han, Q., Yi, P., Ning, H., Li, H., Wang, C., and Zhang, X. .2024. Effects of nutrient solution application rates on yield, quality, and water–fertilizer use efficiency on greenhouse tomatoes using grown-in coir. *Plants* **13**(6): 893. https://doi.org/10.3390/plants13060893.

Mashamaite, C. V., Motsi, H., Manyevere, A., and Poswa, S. B. 2024. Assessing the potential of biochar as a viable alternative to synthetic fertilizers in Sub-Saharan Africa smallholder farming: A review. *Agronomy* **14**(6): 1215. https://doi.org/10.3390/agronomy14061215.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S. and Moher, D. 2021. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* **372**(71):n71. https://doi.org/10.1136/bmj.n71.

Rahman, M. H., Hasan, M. N., Nigar, S., Ma, F., Aly Saad Aly, M., and Khan, M. Z. H. 2021. Synthesis and characterization of a mixed nano fertilizer influencing the nutrient use efficiency, productivity, and nutritive value of tomato fruits. *ACS Omega* **6**(41): 27112–120. https://doi.org/10.1021/acsomega.1c03727.

Research Gate. 2024. Growth, yield, and yield components of tomato varieties (*Solanum lycopersicum* L.) influenced by the application of blended fertilizers (NPS) at Jimma, South-West Ethiopia. *Technical Publication Dataset,* Article 384222415.

Snyder, H. 2019. Literature review as a research methodology: An overview and guidelines. *Journal of Business Research* **104**: 333–39. https://doi.org/10.1016/j.jbusres.2019.07.039.

Stoeva, V. 2026. Agronomic bio fortification in tomato: balancing micronutrient enrichment, yield, and fruit quality. *Frontiers in Plant Science* **17:** 1835095.

Tondey, M., Javed, A., and Tarar, S. H.2025. Nutrient delivery to crops through fertiliser-coated seed: A systematic review. *ActaAgriculturaeScandinavica, Section B — Soil & Plant Science* **75**(1):45–59. https://doi.org/10.1080/09064710.2025.2470170.

White, P. J., and Broadley, M. R. 2009.. Biofortification of crops with seven essential mineral elements often lacking in human diets – iron, zinc, copper, calcium, magnesium, selenium and iodine. *New Phytologist* **182**(1): 49–84. https://doi.org/10.1111/j.1469-8137.2008.02738.x.

Wu, K., Wang, L., Zhang, L., Han, M., Gong, P., Xue, Y., Song, Y., Wu, Z., and Zhang, L. 2024. The impact of applying different fertilizers on greenhouse gas emissions and ammonia volatilization from Northeast spring corn. *Agronomy* **14**(12): 2798. https://doi.org/10.3390/agronomy14122798.

Zaato, P. A. 2025. *Black soldier fly compost enhances productivity and postharvest quality of tomato in Ghana.* World Vegetable Center Technical Report. https://worldveg.tind.io/record/76198.