

Advances in Soybean Cultivation and Utilization: Growth, Nutritional Significance, and Environmental Impacts

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ABSTRACT

Soybean is one of the most significant crops globally, renowned for its versatility and vital role in food production, animal feed, and industrial applications. Originating in East Asia, soybeans have become a cornerstone of global agricultural systems due to their high protein content and adaptability to various climates. This review explores the importance of soybeans, providing a comprehensive overview of their botanical characteristics, ideal growing conditions, and environmental requirements. It examines the diverse uses of soybeans, from traditional food products like tofu and soy milk to their emerging applications in biofuels and industrial products. The review also delves into the soybean growth cycle, highlighting the vegetative and reproductive stages that are essential for optimizing yields. Soybean yield performance is influenced by genetics, environmental conditions, and farming practices, and this review evaluates the factors contributing to global yield trends and the challenges faced by regional producers. Additionally, the economic significance of soybeans is discussed, emphasizing their role in global trade, agricultural policies, and their value in sustainable energy solutions through biodiesel production. Furthermore, the

review addresses the nutrient requirements for optimal soybean cultivation and explores sustainable practices that mitigate environmental impacts associated with soybean farming, such as deforestation and chemical input reliance. The article concludes by identifying future directions for research, focusing on enhancing crop resilience, improving farming practices, and exploring the expanded use of soybeans in biofuels and industrial applications to support global sustainability efforts.

Keywords: Soybeans, Soybean cultivation, Plant-based protein, Sustainable agriculture, Soybean yield

INTRODUCTION

Soybeans (*Glycine max* L. Merr.) are among the most important crops globally, valued for their diverse applications across various industries. Originating in East Asia, soybeans have become a major agricultural product, cultivated worldwide due to their versatility, nutritional value, and environmental benefits. As a rich source of protein, oil, and other essential nutrients, soybeans are integral to global food systems, particularly in the production of plant-based foods such as tofu, soy milk, and soy sauce (Mishra et al., 2024). The crop's significance extends beyond human consumption, as

soybeans are critical in animal feed, biofuel production, and various industrial applications. As the demand for sustainable, plant-based protein continues to rise, soybean's role in meeting these needs grows in importance, reinforcing its status as a global commodity (Amol et al., 2021).

The soybean industry contributes significantly to the economies of many countries, with major producers including the United States, Brazil, Argentina, China, and India. In addition to its nutritional benefits, soybean cultivation offers environmental advantages due to its ability to fix nitrogen, improving soil health and reducing the need for synthetic fertilizers. As a result, soybeans are an essential crop in crop rotation systems, promoting sustainable agricultural practices and enhancing soil fertility (Mozeika et al., 2013). The increasing global population and the corresponding demand for food and biofuels highlight the importance of improving soybean production systems to ensure food security and environmental sustainability.

The purpose of this review article is to provide a comprehensive examination of soybean cultivation and utilization. This article will explore the botanical characteristics of the soybean plant, the ideal growing conditions for its cultivation, and its various uses in food, animal feed, and industrial applications. It will also discuss the growth phases of soybeans, the factors influencing yield performance, and the economic significance of the soybean industry worldwide. Additionally, the review will address the nutrient requirements for optimal soybean cultivation and highlight the environmental impacts associated with soybean farming. By synthesizing current research, this article aims to contribute valuable insights into the future of soybean cultivation and its potential to address global challenges.

METHODS

This review article was developed through an extensive examination of existing literature on soybean cultivation, utilization, and its

environmental and economic impacts. A systematic approach was employed to gather and synthesize relevant studies from a wide range of scholarly sources, including peer-reviewed journals, books, government reports, and industry publications. The methodology followed is outlined below.

1. Literature Search and Selection

The literature search was conducted using a combination of academic databases, including Google Scholar, JSTOR, Scopus, and ScienceDirect. The search terms included keywords such as "soybean cultivation," "soybean yield," "soybean uses," "environmental impact of soybean farming," "economic significance of soybeans," and "sustainable agriculture practices in soybean farming." The articles selected for review were published within the last decade to ensure the incorporation of the most recent advancements and research in soybean science.

2. Inclusion and Exclusion Criteria

Studies were included if they addressed key topics related to soybean cultivation, genetic improvement, environmental sustainability, uses of soybeans, yield performance, and economic significance. Articles discussing specific case studies, such as soybean production in the world, were also included to provide region-specific insights. Exclusion criteria were applied to non-peer-reviewed sources, articles focusing on topics unrelated to soybean cultivation, and those not available in English. Only studies with significant empirical data or expert analysis were considered for inclusion.

3. Data Extraction and Organization

The extracted data were systematically organized into several thematic categories. The first category, Botanical Description, focused on the characteristics of soybean plants, their growth stages, and the ideal environmental conditions required for successful cultivation. The second category, Diverse Uses, explored the various applications of soybeans, including their role

in food production, animal feed, biofuels, and industrial products. In the Yield Performance category, the review examined the factors influencing soybean yield, global yield trends, and the challenges faced by specific regions in maximizing productivity. The Economic Significance category discussed the pivotal role of soybeans in global trade and agriculture, along with their contribution to biofuel production. Lastly, the Environmental Impacts category addressed the environmental challenges associated with soybean farming, emphasizing the importance of sustainable farming practices to mitigate negative environmental effects. These thematic categories provided a comprehensive framework for analyzing and synthesizing the data from the selected studies.

4. Critical Analysis

The selected studies were critically analyzed to assess the consistency of findings, identify gaps in current research, and highlight areas where future studies are needed. Key themes such as the impact of climate change on soybean yield, the potential of genetically modified varieties, and innovations in sustainable farming were explored in detail. This critical analysis helped to identify trends, challenges, and opportunities within the soybean industry.

5. Synthesis and Conclusion

The findings from various studies were synthesized to provide a cohesive overview of soybean cultivation and utilization. The review integrates insights from genetics, agronomy, environmental science, and economics to present a comprehensive understanding of the soybean industry. The conclusions drawn reflect the current state of soybean research and propose future research directions to address emerging challenges in soybean production and sustainability. This methodology ensures that the review article offers an up-to-date, evidence-based, and comprehensive understanding of soybean cultivation, its uses, and its environmental and economic significance.

BOTANICAL DESCRIPTION OF SOYBEANS

Soybeans are herbaceous annual legumes belonging to the Fabaceae family. The plant typically grows between 0.2 and 2 meters in height, with an erect, branching stem that becomes woody at the base as it matures (Fig. 1). Its surface is covered with a fine layer of pubescence (hairy surface), a characteristic trait of soybean plants (Hymowitz & Newell, 1981). The root system of soybeans is vital for the plant's ability to fix nitrogen through its symbiotic relationship with *Rhizobium* bacteria. This process enriches the soil with nitrogen, reducing the need for synthetic fertilizers and contributing to sustainable agricultural practices (USDA, 2024).

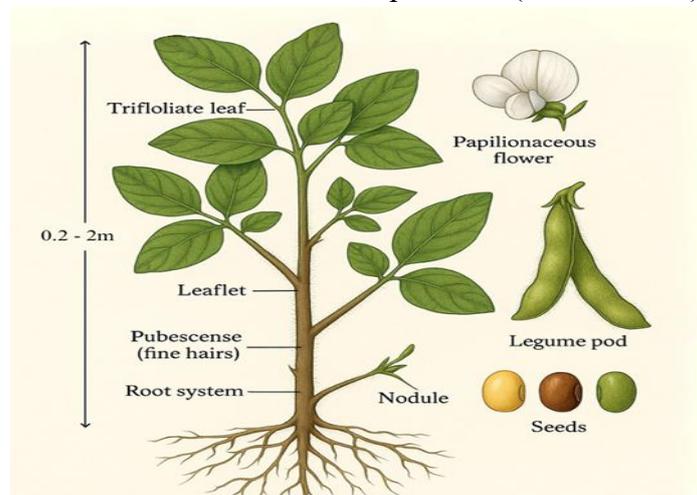


Figure 1: Botanical Features of Soybean | Morphology and Key Structures

Soybean leaves are trifoliolate, with each leaf consisting of three oval to ovate leaflets arranged alternately along the stem. These leaves are the primary sites for photosynthesis, which supports the plant's growth and development (Hymowitz & Newell, 1981). The plant produces papilionaceous (butterfly-shaped) flowers, typically in shades of white, pink, or purple. These flowers exhibit bilateral symmetry and consist of five sepals, five petals, ten stamens (nine fused and one free), and a superior ovary. After pollination, the flowers give way to legume pods, which measure 3 to 8 cm in length and typically contain two to four seeds. Soybean seeds come in various colors, including yellow, green, brown, black, or bicolored (USDA, 2024).

Soybeans thrive in well-drained, fertile soils with adequate moisture. They grow best in soils with a moderately acidic to neutral pH (5.8–7.0) and are suited to temperate to tropical climates (Ernest, 2022). The plant's adaptability to different soil types and climatic conditions has contributed to its widespread cultivation across the globe. Soybeans are typically grown in areas with moderate temperatures, although they can also thrive in tropical regions, making them a versatile crop for various agricultural systems worldwide.

In addition to its ability to fix nitrogen, soybean's root system is also instrumental in enhancing soil structure, promoting better water retention, and reducing soil erosion. This makes soybeans an excellent crop for sustainable farming practices, particularly in crop rotation systems aimed at enhancing soil health and reducing the need for synthetic fertilizers. The plant's broad environmental adaptability, coupled with its beneficial effects on soil fertility, makes it a valuable component of sustainable agricultural systems.

DIVERSE USES OF SOYBEAN

Soybeans are among the most versatile crops globally, with numerous applications spanning food, animal feed, and industrial products. One of the primary reasons for

soybean's widespread use is its high protein content, which ranges between 37% and 48%, making it a unique source of plant-based protein. This makes soybeans a staple ingredient in the production of various food products, including tofu, soy milk, soy sauce, and other traditional Asian food products. These soy-based foods have become increasingly popular worldwide, particularly as consumers shift towards plant-based diets due to health and environmental concerns (Rizzo et al., 2018; Bagale, 2021).

Soybeans also play a crucial role in animal feed production. A significant portion of the global soybean crop is processed into soybean meal, which is used as a high-protein ingredient in livestock and poultry feed. Soybean meal is an excellent source of essential amino acids, promoting growth and productivity in farm animals. Its high protein content makes it particularly valuable in the meat and dairy industries, where it supports the development of livestock and the production of meat, milk, and eggs (Hartman, 2011; Killi & Beycioğlu, 2022). The soybean industry's contribution to the global livestock sector underscores its importance in ensuring food security and supporting agricultural economies.

In addition to its role in food and animal feed, soybeans are a valuable resource in the biofuel industry. Soybean oil, which accounts for 16% to 21% of the seed's composition, can be processed into biodiesel, a renewable and sustainable alternative to traditional fossil fuels. Biodiesel produced from soybeans helps reduce greenhouse gas emissions and dependence on non-renewable energy sources, contributing to global efforts to combat climate change (Neupane, 2022). The increasing demand for renewable energy solutions highlights the growing role of soybeans in promoting sustainability and reducing the environmental impacts associated with traditional energy sources.

Soybeans are also used in various industrial products, including soaps, cosmetics, paints, and lubricants. The oil extracted from soybeans serves as a raw material in these industries, where its versatility and

biodegradable properties make it an attractive alternative to petroleum-based products. As the world continues to seek more sustainable and eco-friendly solutions, soybeans are positioned to play an increasingly important role in the development of biodegradable and renewable industrial products. The growing demand for plant-based proteins and sustainable industrial solutions continues to drive the expansion of soybean cultivation. As consumer preferences shift toward more sustainable and healthy alternatives, soybeans are poised to remain a critical component in the global food, feed, and industrial sectors.

GROWTH PHASES OF SOYBEAN

Soybean growth can be divided into two primary phases: vegetative (V) and reproductive (R). The vegetative stages begin with the emergence of the cotyledons (V1) and continue through the production of additional trifoliolate leaves (V2, V3, etc.), which are crucial for the plant's photosynthetic capacity. The number of trifoliolate leaves produced during this stage is influenced by both genetic factors and the prevailing environmental conditions. The plant's growth during the vegetative stage is essential for developing a strong root system and canopy, both of which are necessary for optimal nutrient uptake and light capture (Singh, 2022).

Table 1. Growth Phases of Soybean: Stages, Characteristics, and Influences

Phase	Stage	Key Characteristics	Environmental & Genetic Influences
Vegetative (V)	V1 – Cotyledon Emergence	Cotyledons emerge; initial root and shoot development begins	Influenced by seed vigor, soil temperature, and moisture
	V2, V3, etc. – Trifoliolate Leaf Development	Sequential emergence of trifoliolate leaves; increase in leaf area for photosynthesis	Affected by genotype, light, nutrients, and weather conditions
	Full Vegetative Growth	Maximum vegetative growth reached before reproductive transition	Dependent on adequate nutrients, water, and growing degree days
Reproductive (R)	R1 – Flowering	First appearance of flowers on the plant	Highly sensitive to temperature and water availability
	R2–R4 – Pod Development	Pods begin to form and elongate after pollination	Dependent on pollination success, nutrient levels, and heat stress
	R5–R6 – Seed Filling	Seeds fill and mature within pods	Influenced by carbohydrate availability, moisture, and temperature
	R7–R8 – Maturity	Pods and leaves begin to dry down; physiological maturity achieved	Controlled by genetic maturity group and environmental conditions

The reproductive phase begins once the plant reaches full vegetative growth, typically marked by the appearance of flowers. During this phase, the plant progresses through flowering, podding, and seeding stages. Flowering marks the initiation of the reproductive process, followed by podding, where the plant forms pods that will eventually contain the seeds. The seeding phase occurs when the seeds fill the pods and mature, signalling the plant's readiness for harvest (Knott & Lee, 2016). These stages

are critical for determining final yield and quality, with the reproductive phase being particularly sensitive to environmental factors such as temperature, water availability, and nutrient supply.

Understanding the growth stages of soybeans is crucial for maximizing crop yield. Environmental stress during the vegetative or reproductive stages can result in significant yield losses. For instance, damage to the plant during flowering or podding can lead to reduced seed formation, while environmental

stress during the vegetative stage can inhibit the plant's ability to develop a strong root system and canopy. Monitoring these growth phases allows farmers to implement timely interventions, such as irrigation, pest control, or fertilization, to optimize plant development and minimize yield losses.

The development of soybean cultivars with improved growth characteristics is an ongoing area of research. By selecting cultivars that are better adapted to specific environmental conditions and growth phases, farmers can enhance productivity and reduce the impact of environmental stressors. Furthermore, advancements in agricultural technologies, such as precision farming and climate-resilient crop varieties, are expected to improve soybean growth management and increase yields in the face of climate change and other challenges. Hence, a comprehensive understanding of the vegetative and reproductive phases of soybean growth is essential for effective crop management. By optimizing conditions

during these phases and selecting appropriate cultivars, farmers can enhance soybean productivity and reduce the risk of yield loss due to environmental stressors.

SOYBEAN YIELD PERFORMANCE

The yield of soybeans is influenced by a combination of genetic, environmental, and management factors, which together determine the plant's overall productivity. Genetically, different soybean cultivars exhibit variations in yield potential, which is largely influenced by their growth habits, resistance to pests and diseases, and their ability to tolerate environmental stressors. Advances in genetic breeding have led to the development of high-yielding soybean varieties that perform better in diverse environmental conditions. For instance, modern cultivars have been developed to withstand drought, disease, and temperature fluctuations, all of which can significantly impact yield (Vogel et al., 2021).

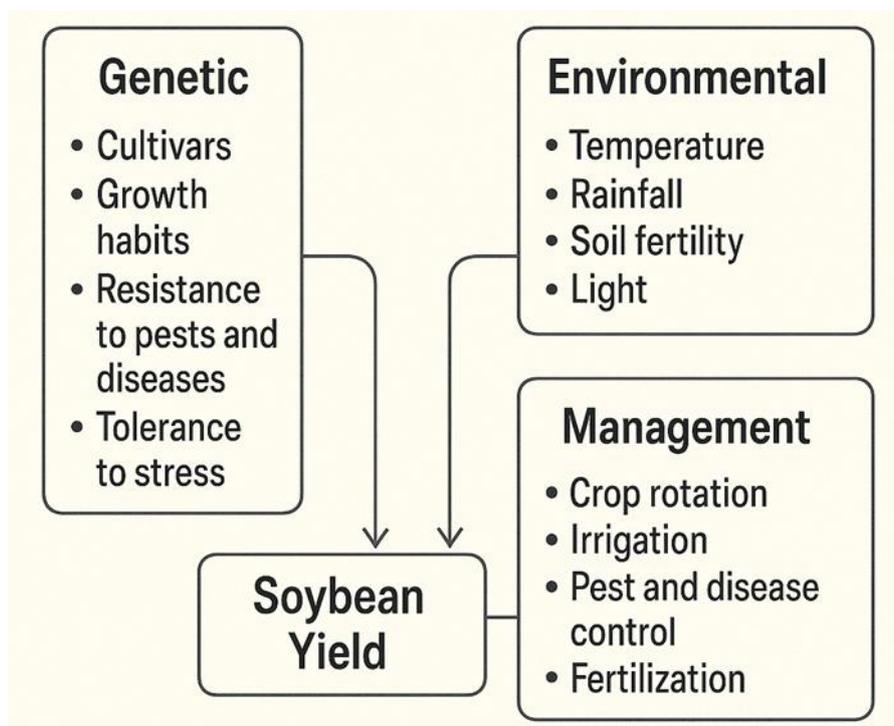


Figure 2: Schematic Diagram of Key Factors Influencing Soybean Yield

Environmental conditions, including temperature, rainfall, soil fertility, and light availability, are critical determinants of

soybean yield. Soybeans are sensitive to both extremes of temperature, with optimal growth occurring between 20°C and 30°C.

Stress during flowering or pod-setting due to high temperatures or inadequate water supply can result in pod abortion, reduced seed size, and ultimately, lower yields. Similarly, poor soil fertility or inadequate nutrient management can limit soybean growth and result in suboptimal yields. Soil pH also plays a significant role, as soybeans prefer mildly acidic to neutral soils for optimal nutrient uptake (Schulze et al., 2006).

Farming practices, including crop rotation, irrigation, pest and disease management, and fertilization, also contribute to soybean yield. Effective pest and disease management can reduce the risk of crop loss, while optimal irrigation practices ensure that the plants receive adequate water during critical growth phases. Fertilization practices, particularly the application of nitrogen, phosphorus, and potassium, are essential for maximizing soybean productivity. Furthermore, the use of organic and synthetic fertilizers, depending on the region, can enhance soil health and promote higher yields (Bagale, 2021).

Global soybean yield trends have shown a steady increase due to technological advancements in breeding, farming practices, and pest control. The average global soybean yield has improved from 1,128 kg/ha to 2,769 kg/ha in recent years (Van Roekel et al., 2015). However, region-specific challenges continue to affect yield performance. In areas like Southeast Asia and parts of Africa, low-quality planting materials, insufficient access to modern agricultural technologies, and poor soil health have hindered soybean productivity. In contrast, regions such as North and South America, which have better access to advanced farming technologies and infrastructure, experience significantly higher yields (Flajšman et al., 2019).

In tropical countries like the Philippines, challenges such as inconsistent rainfall, pests, and poor-quality seeds have contributed to relatively low soybean yields, with farmers achieving around 1 ton per hectare in some regions (Balanay & Laureta,

2021). Addressing these challenges through better seed quality, improved irrigation systems, and more efficient pest management could substantially improve yields in the country. Therefore, soybean yield performance is determined by an intricate interplay of genetics, environmental factors, and farming practices, and efforts to address these factors can help boost global and regional productivity.

THE SOYBEAN INDUSTRY IN THE WORLD

The global soybean industry plays a pivotal role in agricultural economies, particularly in countries like the United States, Brazil, Argentina, China, and India, which are among the leading producers of this essential crop. In the United States, for example, soybeans are cultivated across vast regions, particularly in the Midwest, and are a key component of the agricultural sector, generating billions of dollars in revenue annually. Brazil and Argentina also play major roles in the global soybean market, with Brazil recently surpassing the U.S. as the world's top exporter of soybeans. Soybean production in these countries is closely tied to their agricultural policies, land use practices, and access to global markets. However, despite the success of major producers, the soybean industry faces significant challenges, particularly in regions with less developed agricultural systems. In the Philippines, for example, soybean cultivation is limited, and the country remains a net importer of soybeans. The major challenges faced by Philippine soybean farmers include a lack of access to high-quality seeds, poor soil quality, and vulnerability to pests and diseases (Corpuz, 2018). Additionally, inconsistent weather patterns, including droughts and heavy rainfall, further exacerbate the challenges in soybean production. These factors contribute to the relatively low productivity in the Philippines, where soybean is primarily used for animal feed rather than human consumption (Cejalvo & Mercado, 2018).

Efforts to address these challenges in the Philippines include the introduction of high-yielding and disease-resistant soybean varieties, as well as improvements in farming practices and infrastructure. The government and agricultural institutions are working to promote sustainable soybean farming through research, extension services, and policy initiatives aimed at improving seed quality and providing access to modern agricultural technologies. The promotion of soybean as a viable crop for local farmers could reduce dependency on imports and increase domestic production, thus boosting the local economy and contributing to food security.

At the global level, the soybean industry faces other challenges, such as fluctuating commodity prices, trade restrictions, and the environmental impact of large-scale monoculture farming. As the demand for soybeans increases, there is growing pressure on producers to adopt sustainable farming practices to mitigate environmental degradation and reduce greenhouse gas emissions. The future of the soybean industry will depend on its ability to address these challenges while meeting the growing global demand for this essential crop.

ECONOMIC SIGNIFICANCE OF SOYBEANS

Soybeans are a vital agricultural commodity that has substantial economic value, particularly in countries that are major producers and exporters. The United States, for instance, is one of the largest producers of soybeans, contributing significantly to both the domestic and global economy. In addition to its role in food production, soybeans are an essential component in the animal feed industry, where soybean meal is used as a high-protein feed for livestock and poultry. This demand for soybean meal has made soybeans a crucial crop in the meat production industry, supporting the global meat and dairy markets (Guo et al., 2018).

Soybean trade is a major component of global agricultural markets, with countries like Brazil and Argentina playing key roles

in soybean exports. As global demand for soybeans continues to rise, particularly from China, the trade dynamics of the soybean industry are continually shifting. The U.S. and Brazil are major exporters of soybeans, while countries like China have become major importers to meet the demands of their growing population. Soybean trade also affects global agricultural policies, as governments of producing countries seek to maintain competitive pricing and ensure the sustainability of production systems (Boerema et al., 2016).

The economic value of soybeans extends beyond food and feed to include industrial applications, such as biodiesel production. Soybean oil is a key ingredient in biodiesel, a renewable energy source that helps reduce greenhouse gas emissions and dependence on fossil fuels. The growing demand for sustainable energy sources further enhances the economic importance of soybeans. As the world transitions to more eco-friendly and sustainable energy options, soybeans will continue to play a crucial role in the biofuel industry (Neupane, 2022).

However, the soybean industry faces challenges related to price volatility, trade barriers, and competition from other oilseeds. The relaxation of soybean import restrictions in countries like China has altered global market dynamics, leading to fluctuations in soybean prices. These price fluctuations can impact both producers and consumers, particularly in countries that rely heavily on soybean imports for food and feed. To ensure stability, global efforts to regulate the soybean market and implement policies that support sustainable production practices are crucial. With this, soybeans have a significant economic impact on global agriculture, supporting a wide range of industries from food production to biofuels. As global demand for soybeans continues to grow, the industry must adapt to changing market conditions, trade policies, and sustainability concerns to maintain its economic viability and contribute to global food security.

NUTRIENT REQUIREMENTS FOR OPTIMAL SOYBEAN CULTIVATION

Soybeans require a variety of nutrients for optimal growth and productivity, and effective nutrient management is essential for maximizing yield. Soybean plants require six primary macronutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). These nutrients are needed in large quantities and are essential for various physiological functions, such as chlorophyll production, enzyme activation, and cell structure formation. Additionally, soybeans require nine micronutrients in smaller quantities, including iron (Fe), boron (B), zinc (Zn), and copper (Cu), which are essential for enzymatic activities and plant metabolism (Bagale, 2021).

Nitrogen is particularly important for soybeans because it plays a vital role in chlorophyll and enzyme production. Soybeans have the unique ability to fix nitrogen from the atmosphere through their symbiotic relationship with *Rhizobium* bacteria in their root nodules. This process reduces the need for synthetic nitrogen fertilizers, making soybeans an environmentally friendly crop in terms of nutrient management (Li et al., 2024). Phosphorus and potassium are also critical, as they influence seed yield, protein content, and stress management. Sulfur is necessary for seed growth and productivity, while calcium and magnesium help stabilize cell walls and support energy metabolism in the plant (Clarkson & Hanson, 1980; Schulze et al., 2006).

To optimize soybean productivity, it is essential to balance the application of these nutrients through soil management or commercial fertilizers. The availability of these nutrients depends on several factors, including soil pH, organic matter content, and fertilizer application techniques. Modern soybean varieties tend to remove more nutrients from the soil compared to older cultivars, which means that nutrient management practices must evolve to ensure that the soil remains fertile and capable of

supporting high-yielding crops. Additionally, managing the interactions between different nutrients and ensuring that micronutrients are available in the right amounts is crucial for maximizing soybean growth and yield (Neto et al., 2021).

ENVIRONMENTAL IMPACTS OF SOYBEAN PRODUCTION

Soybean farming, like any large-scale agricultural practice, has significant environmental implications. One of the main environmental concerns associated with soybean production is deforestation, particularly in countries like Brazil, where large tracts of forested land are cleared for soybean plantations. This deforestation contributes to habitat loss, biodiversity decline, and increased greenhouse gas emissions (Nagal, 2025). The expansion of soybean farming into previously undisturbed ecosystems, such as the Amazon rainforest, has been a source of environmental and social controversy (Da Silva et al., 2022).

Another environmental issue is the excessive use of chemical fertilizers and pesticides, which can lead to soil degradation, water contamination, and loss of soil biodiversity. While soybeans are relatively efficient in nitrogen fixation, their high demand for other nutrients, such as phosphorus and potassium, can lead to over-reliance on synthetic fertilizers, which may degrade soil quality over time (Schulze et al., 2006). Moreover, pesticide use to control pests and diseases can harm non-target species and disrupt local ecosystems.

To mitigate these environmental impacts, sustainable farming practices are being promoted, including reduced pesticide use, integrated pest management, and soil conservation techniques. Additionally, agroforestry and crop rotation practices, which combine soybean cultivation with trees or other crops, are being implemented to enhance biodiversity, reduce erosion, and improve soil fertility. The adoption of no-till farming practices has also been advocated to reduce soil erosion and improve water retention (Vogel et al., 2021).

Innovations in biotechnology are also helping to address environmental concerns. For example, the development of genetically modified (GM) soybeans that are resistant to pests or require fewer chemical inputs could reduce the environmental footprint of soybean farming. Furthermore, advancements in precision agriculture, which involves using technology to monitor and optimize inputs, can help farmers use fertilizers and pesticides more efficiently, reducing their environmental impact (Rincker et al., 2014).

CONCLUSION

Soybeans are an indispensable crop with profound economic, nutritional, and environmental significance globally. This review has highlighted the crucial role of soybeans in various industries, particularly in food production, animal feed, biofuels, and industrial applications. Soybeans are not only a rich source of plant-based protein and essential nutrients but also offer environmental benefits, such as nitrogen fixation, which enhances soil health and reduces the need for synthetic fertilizers. The crop's adaptability to different climates and its multifaceted uses underscores its importance in ensuring food security and promoting sustainable agricultural practices. However, despite the broad benefits of soybean cultivation, several challenges remain, particularly regarding yield optimization, environmental sustainability, and regional production disparities. Global yield trends have shown steady growth, primarily driven by advancements in genetic breeding and improved farming practices. Yet, factors such as climate change, pests, soil degradation, and inconsistent access to high-quality seeds continue to impact soybean productivity, particularly in developing regions like the Philippines. Addressing these challenges requires enhanced agricultural infrastructure, better pest and disease management, and the promotion of climate-resilient soybean varieties.

The economic value of soybeans is immense, particularly in the animal feed industry and biofuel production. As the demand for plant-based proteins and sustainable energy solutions increases, soybeans will play a critical role in meeting these needs. However, issues related to deforestation, excessive chemical use, and monoculture farming highlight the need for sustainable farming practices. Innovations in biotechnology and precision agriculture hold promise for mitigating these environmental challenges and improving the sustainability of soybean production.

Future research should focus on developing genetically modified soybeans that are more resilient to environmental stressors, optimizing nutrient management strategies, and exploring the expanded use of soybeans in renewable energy and industrial applications. As the global demand for soybeans continues to rise, ensuring that production systems are efficient, sustainable, and resilient will be essential to meeting the growing needs of a changing world.

Declaration by Authors

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REFERENCES

1. Amol, V., Bhati, K. R., & Bhati, K. R. (2021). Nutritive Benefits of Soybean (*Glycine max*). *The Indian Journal of Nutrition and Dietetics*, 522–533. <https://doi.org/10.21048/ijnd.2021.58.4.27339>
2. Bagale, S. (2021). Nutrient management for soybean crops. *International Journal of Agronomy*, 2021, 1–10. <https://doi.org/10.1155/2021/3304634>
3. Balanay, R., & Laureta, R. (2021). Towards boosting the supply chain of soybeans for food security and import substitution in Caraga region, Philippines. <https://journals.carsu.edu.ph/JESEG/article/view/38>
4. Boerema, A., Peeters, A., Swolfs, S., Vandevenne, F., Jacobs, S., Staes, J., & Meire, P. (2016). *Soybean Trade: Balancing*

- Environmental and Socio-Economic Impacts of an intercontinental market. *PloS One*, 11(5), e0155222. <https://doi.org/10.1371/journal.pone.0155222>
5. Cejalvo, R. D., & Mercado, M. F. O. (2019). Presoaking treatment of soybean (*Glycine max* L. Merrill) seeds using fermented plant extracts and commercial liquid fertilizer. *JPAIR Multidisciplinary Research*, 34(1). <https://doi.org/10.7719/jpair.v34i1.628>
 6. Clarkson, D. T., & Hanson, J. B. (1980). The mineral nutrition of higher plants. *Annual Review of Plant Physiology*, 31(1), 239–298. <https://doi.org/10.1146/annurev.pp.31.060180.001323>
 7. Corpuz, P. (2018). Philippine oilseeds and product situation outlook (GAIN Report No. RP 1802). USDA Foreign Agricultural Service. <https://www.apps.fas.usda.gov/newgainapi/api/report/3-16-2018>
 8. Da Silva, A. F., Silva, F. C. D. S., Bezerra, A. R. G., Sedyama, T., Rosa, D. P., & Barros, J. P. A. (2022). SELECTION OF PODS IN F4:5 GENERATION OF SOYBEAN TO UNDERSTAND ASSOCIATION BETWEEN YIELD COMPONENTS USING PATH ANALYSIS IN THE GREENHOUSE AND FIELD ENVIRONMENTS. *Functional Plant Breeding Journal*, 4(2), 23–31. <https://doi.org/10.35418/2526-4117/v4n2a3>
 9. Ernest, E. G. (2022). Dramatic Potassium Deficiencies are Appearing in Soybean Fields | Weekly Crop Update. <https://sites.udel.edu/weeklycropupdate/?p=7365>
 10. Flajšman, M., Šantavec, I., Kolmanič, A., Košmelj, K., & Kocjan-Ačko, D. (2019). Agronomic performance and stability of seed, protein and oil yields of seven soybean cultivars determined in field experiments in Slovenia. <https://doiserbia.nb.rs/Article.aspx?ID=0534-00121901031>
 11. Guo, J., Li, Z., Su, L., Tsang, Y., An, A., & Yu, C. (2018). Optimization of acid pretreatment and enzymatic hydrolysis on the production of ethanol fuel from waste banana peels. *Energy & Environment*, 29(8), 1354–1364. <https://doi.org/10.1177/0958305x18777232>
 12. Hartman, G. L., West, E. D., & Herman, T. K. (2011). Crops that feed the World 2. Soybean—worldwide production, use, and constraints caused by pathogens and pests. *Food Security*, 3(1), 5–17. <https://doi.org/10.1007/s12571-010-0108-x>
 13. Hymowitz, T., & Newell, C. A. (1981). Taxonomy of the genus. *Glycine*, domestication and uses of soybeans. *Economic Botany*, 35(3), 272–288. <https://doi.org/10.1007/bf02859119>
 14. Killi, F., & Beycioğlu, T. (2022). GENETIC AND ENVIRONMENTAL VARIABILITY, HERITABILITY AND GENETIC ADVANCE IN POD YIELD, YIELD COMPONENTS, OIL AND PROTEIN CONTENT OF PEANUT VARIETIES. *Turkish Journal of Field Crops*, 27(1), 71–77. <https://doi.org/10.17557/tjfc.1050448>
 15. Knott, C., & Lee, C. (2016). Identifying Soybean Growth Stages. *Plant and Soil Science*. <https://www2.ca.uky.edu/agcomm/pubs/AGR/AGR223/AGR223.pdf>
 16. Li, H., Lehmann, A., Rongstock, R., Xu, Y., Kunze, E., Meidl, P., & Rillig, M. C. (2024). Diversity of organic amendments increases soil functions and plant growth. *Plants People Planet*, 7(1), 80–86. <https://doi.org/10.1002/ppp3.10588>
 17. Mishra, R., Tripathi, M. K., Sikarwar, R. S., Singh, Y., & Tripathi, N. (2024). Soybean (*Glycine max* L. Merrill): A Multipurpose Legume Shaping Our World. *PLANT CELL BIOTECHNOLOGY AND MOLECULAR BIOLOGY*, 25(3–4), 17–37. <https://doi.org/10.56557/pcbmb/2024/v25i3-48643>
 18. Mozeika, M., Bernardes, G., & Villavicencio, A. L. C. H. (2013). Soybean and isoflavones – from farm to fork. In *InTech eBooks*. <https://doi.org/10.5772/52609>
 19. Nagal, C. J. C. (2025). Harvesting Traditions: Exploring the Indigenous agricultural knowledge systems in Java, Indonesia and Mindanao, Philippines. *Millennial Asia*. <https://doi.org/10.1177/09763996251327672>
 20. Neupane, D. (2022). Biofuels from Renewable Sources, a Potential Option for Biodiesel Production. *Bioengineering*, 10(1), 29. <https://doi.org/10.3390/bioengineering10010029>

21. Rincker, K., Nelson, R., Specht, J., Sleper, D., Cary, T., Cianzio, S. R. (2014). Genetic Improvement of U.S. Soybean in Maturity Groups II, III, and IV. *Crop Sci.* 54, 1419–1432. doi: 10.2135/cropsci2013.10.0665
22. Rizzo, G., & Baroni, L. (2018). Soy, soy foods and their role in vegetarian diets. *Nutrients*, 10(1), 43. <https://doi.org/10.3390/nu10010043>
23. Schulze, J., Temple, G., Temple, S. J., Beschow, H., & Vance, C. P. (2006). Nitrogen Fixation by White Lupin under Phosphorus Deficiency. *Annals of Botany*, 98(4), 731–740. <https://doi.org/10.1093/aob/mcl154>
24. Singh, M. (2022). Corn and soybean planting decisions for uniform emergence and optimal yield. Michigan State University. https://www.canr.msu.edu/agronomy/2022_maba_singh.pdf
25. USDA. Plants Database. (2024). <https://plants.usda.gov/home/plantProfile?symbol=GLMA4>
26. Van Roekel, R. J., Purcell, L. C., and Salmerón, M. (2015). Physiological and management factors contributing to soybean potential yield. *Field Crops Res.* 182, 86–97. doi: 10.1016/j.fcr.2015.05.018
27. Vogel, J. T., Liu, W., Olhoft, P., Crafts-Brandner, S. J., Pennycooke, J. C., & Christiansen, N. (2021). Soybean Yield Formation Physiology – a foundation for precision breeding-based improvement. *Frontiers in Plant Science*, 12. <https://doi.org/10.3389/fpls.2021.719706>

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