

Oryza sativa L

MONOGRAPH



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1.0 INTRODUCTION

Oryza sativa L is one of the most important cultivated plant species worldwide, serving as a foundational component of global food systems and human nutrition. As a member of the Poaceae family, it has undergone a long process of domestication from wild grass species in Asia, resulting in a crop that is both highly productive and widely adaptable to diverse environmental conditions. Its ability to grow in flooded lowlands, rainfed fields, and even marginal environments has allowed it to expand across continents and become a central element of agricultural systems worldwide.

This monograph presents a comprehensive scientific analysis of *Oryza sativa L*, beginning with its origin, evolution, and ecological distribution. It then examines the environmental conditions required for its growth, including climate, soil water and light. The biological characteristics of the species are explored through its life cycle, reproductive processes, and physiological responses to environmental stress. In addition, the study addresses propagation techniques, cultivation practices and pest and disease management strategies that are essential for successful production. Finally the economic importance and diverse applications of rice are discussed, emphasizing its role as both a staple food and a globally significant agricultural commodity.

2.0 Agroecology

2.0.1 Taxonomy

Table 1

Taxonomy of *Oryza sativa* L

Classification	Taxon name
Kingdom	<i>Plantae - plants</i>
Subkingdom	<i>Tracheobionta - vascular plants</i>
Superdivision	<i>Spermatophyta - seed plants</i>
Division	<i>Magnoliophyta - flowering plants</i>
Class	<i>Liliopsida - monocotyledons</i>
Subclass	<i>Commelinidae</i>
Order	<i>Cyperales</i>
Family	<i>Poaceae Barnhat- Grass family</i>
Genus	<i>Oryza L- rice</i>
Species	<i>Oryza Sativa L- rice</i>

Note: table amended from data collected from USDA Plant Database (USDA, 2025)

2.1 Botanical authority

The accepted scientific name of rice is *Oryza Sativa* L. The “L” stands for Carolus Linnaeus, the Swedish botanist who first validly published the species in his “Species Plantarum” (1753). The original description is found in Species Plantarum (Linnaeus, 1753, #). Because no name parentheses appears before the “L”, this indicates Linnaeus’s original placement of the species in the genus *Oryza* has remained valid.

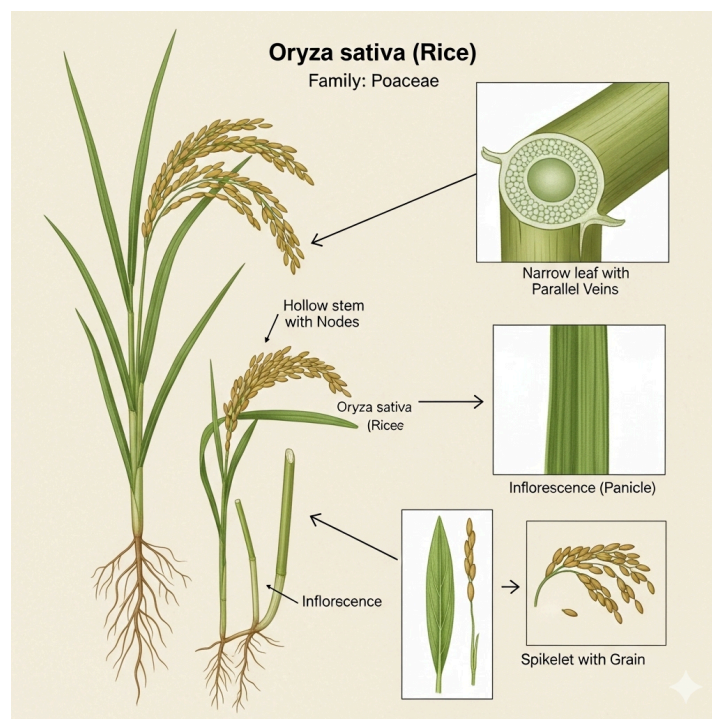
2.2 Taxonomy

The rice plant (*Oryza sativa* L) is classified within the kingdom *Plantae*, which includes all multicellular organisms capable of photosynthesis and characterized by cellulose-based cell walls (USDA, 2025). Within this Kingdom, rice is a part of the subkingdom *Tracheobionta*, the vascular plants, which possess lignified xylem and phloem that allow for the efficient transport of water and nutrients throughout the plant body (USDA, 2025).

From there, rice is classified in the superdivision Spermatophyta, the seed plants, which reproduce through seeds that contain an embryo and stored food reserves, improving dispersal and survival compared to spore-bearing plants (USDA, 2025). Within seed plants, rice belongs to the division Magnoliophyta, the flowering plants or angiosperms, which are defined by their production of flowers and seed enclosed within ovaries that develop into fruits (USDA, 2025).

Rice is further placed in the class Liliopsida, or monocotyledons, which are characterized by having a single seed leaf (cotyledon), parallel venation in leaves, and fibrous root systems (USDA, 2025). It belongs to the subclass Commelinidae, a monocot group that includes grasses and sedges. At the order level, USDA list rice under Cyperales, although modern systems place it within *Poales* (Kress & Reznicek, 2008), both consist of wind-pollinated herbs with small flowers aggregated into spikelets (USDA, 2025).

Within this order, rice is classified in the family Poaceae, the true grasses. Members of this family are distinguished by hollow stems with nodes, narrow leaves with parallel veins, and inflorescences organized into spikelets that produce grains as their fruit type. (Britannica, 2025)



The genus *Oryza* contains about 24 species of grasses adapted to wetland habitats, including both domesticated and wild rice species. Today, *Oryza sativa* remains as the most widely cultivated rice species and one of the world's most important cereal crops.

2.3 Fossil records

The origin of the genus *Oryza* is traced to tropical regions of Asia and Africa. Fossil evidence of wild relatives of rice indicates that grasses related to *Oryza* were present in Asia at least 10-15 million years ago (Khush, 1997). These ancestral forms eventually gave rise to modern cultivated rice. Archaeological remains of rice grains and husk in China domestication of *Oryza* around 9,000 years ago, making rice one of the earliest domesticated cereals.

2.4 Origin and current distribution

Early cultivation of rice occurred in several regions including; China, India and southeast Asia. The oldest archaeological evidence derives from central and eastern China, dating from 7000 to 5000 BCE (Yen, 2025). From these centers, rice spread throughout Asia and was later introduced to Africa, Europe and later on in America through trade and colonization.

Today *Oryza sativa* is grown in every inhabited continent. Data shows that over 90% of global production occurs in Asia, primarily in China, India, Indonesia, and other countries in Asia (FAOSTAT, 2024). Outside Asia rice is cultivated in many other countries and continents.

2.5 Ecoregion

Oryza sativa L. grows predominantly in tropical and subtropical ecoregions, where high humidity, abundant rainfall, and warm temperatures favor its growth. The species evolved from wetland and floodplain ecosystems, and this ancestry explains its unique tolerance to water-saturated soils (Khush, 1997).

Rice cultivation occurs mainly in lowland valleys, river deltas and coastal plains that can sustain prolonged flooding. These include the plains of India and Pakistan, Vietnam and Myanmar. The crop also extends to terraced hillsides in mountainous regions, such as the Philippines, Thailand, and Himalayas (US Department of Agriculture, 2025) (FAO, 2015).

Rice is cultivated from 100 up to 2000 meters from sea level, but the majority of the production takes place below 1,500 meters, where the water and temperature conditions remain ideal (Cambridge University Press, 2020, 1). The crop thrives in tropical monsoon and humid subtropical zones, though irrigation has allowed expansion into temperate regions of Japan, Italy, Spain, etc (Britannica, 2025).

Ecologically, rice is a heliophilous (sun-loving) species that grows in open fields under full sunlight. It is not a forest understory plant, instead, it forms dense monocultures in flat, open landscape where flooding helps control competing vegetation

2.6 Climate

Rice requires a warm and humid climate throughout its growth cycle (Britannica, 2025). The crop performs best in tropical and subtropical regions with abundant water and solar radiation. Optimal growth occurs at temperatures between 20-35 °C (Britannica, 2025). For flowering and grain filling the ideal is between 25-28 °C (FAO, 2020).

Annual rainfall between 1000-2000 millimeters is typically required, distributed evenly during the growing season. In monsoon climates, the natural pattern of seasonal rainfall aligns perfectly with rice's need for standing water. In drier or temperate regions, irrigation replaces rainfall, allowing rice to be grown in areas such as Egypt and Spain (FAO, 2020), (FAOSTAT, 2024).

Ecologists recognize five principal rice ecosystems: irrigated, rainfed upland, rainfed lowland, deepwater, and tidal wetland systems (FAO et al., 2004, 1). Each system reflects unique hydrological and climate conditions, from permanently flooded paddy fields in Asia to rainfed upland fields in Africa and Latin America.

2.7 Climate

Oryza Sativa L. has evolved to grow in floodplain and alluvial landscapes, where soils are shaped by sedimentary geological processes and periodic waterlogging (FAO, 2020). These soils typically develop over alluvial deposits of silt, clay, and fine sand, derived from the weathering of parent rocks such as granite, basalt and shale. The resulting sediments form deep, fine textured soils with a high nutrient reserve and excellent moisture retention, creating ideal conditions for rice cultivation (Cambridge University Press, 2020, 1).

From a textural standpoint, *Oryza sativa L.* grows best in clayey to silty-clay soils, with a clay content of 30-50%. These fine particles reduce percolation and drainage, allowing water to pond (an essential feature for lowland rice ecosystems). Such soils become anaerobic (oxygen poor) when flooded, but rice roots can survive due to specialized tissues called aerenchyma, which transport oxygen internally (Yen, 2025). These anaerobic conditions also activate soil-reducing bacteria that transform unavailable nutrients into plant usable forms, such as ammonium nitrogen and soluble iron (Science Direct, 2018, 1).

Regarding soil chemistry, rice grows most effectively in soils that approach neutral acidity, with one study identifying that the suitable soil pH for rice cultivation is 6 in acid-sulfate soils (Abdul Halim et al., 2018, 1). In such near-neutral soils conditions, nutrient availability (nitrogen, phosphorus, potassium) is maximised while toxic elements like aluminium and iron are kept in tolerable levels. The referenced study also confirms that when soils are extremely acidic (pH 3.7 in untreated acid-sulfate soils) rice yield remains very low until amendments raise pH toward the favourable range (Abdul Halim et al., 2018, 1). At the other extreme, alkaline or strongly sodic soils (pH>8) can impair nutrient uptake, particularly zinc and iron, resulting in chlorosis, restricted root growth and reduced grain yield.

Solid organic matter plays a key role in *Oryza sativa L.* productivity, contributing to soil aggregation, microbial activity, and long-term fertility. Productive paddy soils typically contain between 2-5% organic matter, depending on management and cropping intensity (FAO, 2020). Continuous flooding slows organic decomposition, promoting the accumulation of humus and

enhancing soil nitrogen reserves. In contrast, upland rice systems, which are not flooded, tend to have lower organic matter and nutrient availability due to greater aeration and leaching losses (FAO et al., 2004, 2).

In terms of drainage, rice thrives in poorly drained soils that retain water during the growing season. These conditions are beneficial for lowland rice but unsuitable for most other cereals. Upland rice, however, is adapted to well-drained loamy soils formed on gentle slopes and weathered volcanic or metamorphic rocks, which are less fertile but allow rainfall infiltration (FAO et al., 2004, 2). The geological diversity of these regions (from alluvial plains to volcanic uplands), provides the basis of rice's adaptation to different water regimes.

Finally, salinity and sodicity are major geological constraints in coastal and deltaic areas where seawater intrusion alters soils chemistry. While most rice varieties are sensitive to salinity, some landraces have developed tolerance to moderate salinity levels (up to 4dS/m), allowing cultivation in the Ganges Delta, Mekong delta, and coastal China (Cambridge University Press, 2020, 3).

2.8 Water

Oryza sativa L is globally recognized as the most water-intensive cereal crop, primarily due to its cultivation in flooded paddy systems. On average, 900 to 2250 mm of water per growing season are required for irrigated rice, depending on soil type, climate, and management (FAO et al., 2004, 1). This includes water used for land preparation (150-250mm), evapotranspiration (500-1200mm), seepage and percolation (200-700mm), and mid-season drainage and reflooding (50-100) (FAO et al., 2004, 1).

Continuous flooding throughout most of the growing cycle not only supplies water but also suppresses weeds, stabilizes soil temperature, and maintains anaerobic conditions that favor nitrogen conversation. Nevertheless, modern systems increasingly adopt alternate wetting and drying (AWD) irrigation to reduce water consumption by 25-30% without yield loss, while also decreasing methane emissions (FAO, 2020).

The timing of water availability is critical:

- During germination and tillering, a shallow water layer (2-5cm) is sufficient.
- During panicle initiation and flowering, continuous flooding (5-10cm) prevents sterility due to water stress.
- As grains mature, water levels gradually reduced and fields are drained before harvest to allow soil drying

(Cambridge University Press, 2020, 1).

In upland rice systems, which lack permanent flooding, rainfall must total 1000-1500 mm during the growing season, evenly distributed over 3-4 months (Yen, 2025). Short dry spells of 10-15 days can drastically reduce yield if they occur during the flowering stage, a period highly sensitive to water deficit. Conversely, deep-water rice varieties survive temporary submergence in floods up to 50-100 cm deep (FAO et al., 2004, 2).

2.9 Light and temperature

Oryza sativa L is a tropical and subtropical plant that requires abundant sunlight and warm temperatures throughout its growth cycle. It is a heliophytic species, meaning it thrives in full sunlight, and does not grow well under shaded conditions (Yen, 2025).

Temperature Regime

Oryza sativa L exhibits optimal growth where daytime temperatures average 25-35 degrees celsius and nighttime temperatures stay above 20 degrees celsius (FAO, 2020) (Cambridge University Press, 2020, 2).

- Germination begins at above 12-13 degrees celsius but slows below 15 degrees celsius.
- Tillering and vegetative growth are most vigorous between 25-30 degrees celsius.
- Flowering and grain filling are optimal at 27-30 degrees celsius, and sterility occurs if temperatures fall below 20 or exceed 35 degrees celsius.

Light requirements

Oryza sativa L demands high light intensity and long daily exposure. Although *Oryza sativa* varieties differ in photoperiod sensitivity, most high-yielding types are short-day plants, initiating flowering when day length shortens below about 12 hours (Yen, 2025).

Light influences both photosynthetic rate and grain yield, with studies showing that shading of 50 % can reduce yield by up to 60 % (Abdul Halim et al., 2018, 3). Thus, open, flat fields are ideal, and canopy closure should be uniform to maximize light interception.

3.0 Biology

3.1 Chromosome Complement

Oryza Sativa L. normally contains 24 chromosomes $2n=24$, which means that they are 12 pairs (Rahman et al., 2020, #). These chromosomes contain approximately 50,000 genes that are made up of 430 million chemical subunits called bases of DNA (Berkelaar, 2001).

3.2 Life Cycle and Phenology

Oryza Sativa L. is an annual grass species with a well-defined life cycle divided into vegetative, reproductive, and ripening phases. The growth stages begin with germination, followed by seedling establishment and tillering during the vegetative phase. The reproductive phase includes panicle initiation, flowering, and grain filling, followed by physiological maturity and senescence.

Rice phenology is often categorized into late vegetative, reproductive, and ripening stages, each strongly influencing final yield (Nazir, 2021). Growth duration varies by cultivar and environment but typically ranges from 90 to 180 days depending on temperature, photoperiod sensitivity, and water availability.

Phenological development in rice is influenced by environmental factors such as temperature, day length, and soil moisture. Which regulate tiller formation, flowering time, and grain development.

3.3 Reproductive Biology and Pollination

Rice is predominantly a self-pollinated species, with flowers containing both male and female reproductive organs enclosed within spikelets. Anthesis generally occur in the morning, and pollination typically happens before the spikelet opens, ensuring a high rate of self-fertilization. Cross-pollination occurs at low frequencies but is exploited in breeding programs to introduce genetic diversity (*Rice | Description, History, Cultivation, & Uses*, 2026).

3.4 Physiological Responses to Temperature and Environmental Stress

Rice is a thermophilic crop adapted to warm climates. Optimal growth occurs at mean temperatures between 20°C and 35°C, with germination and early growth requiring temperatures above 10°C. High temperatures during flowering can reduce pollen viability and grain set, whereas low temperatures can delay phenological development and reduce yield (Nguu Van Nguyen, 2004, #).

Rice exhibits several physiological adaptations to environmental stress, particularly flooding. The plant develops aerenchyma tissue in roots and stems, allowing oxygen transport to submerged tissues. Some rice varieties possess genetic tolerance to submergence and drought, reflecting adaptation to diverse agroecological environments such as irrigated paddies, rainfed lowlands, and upland systems (Nguu Van Nguyen, 2004, #).

Water stress, salinity, and temperature extremes affect photosynthesis, tillering, and grain filling, making rice highly sensitive to environmental conditions during the reproductive stage. Breeding programs focus on improving stress tolerance to enhance productivity under climate variability.

4.0 Propagation and management

4.1 Natural regeneration

Natural regeneration in rice refers to the ability of the plant to establish new growth without complete replanting by seed each season. In traditional and low input systems, rice can regenerate through seeds that remain in the field after harvest. These leftover grains may germinate under suitable conditions, producing volunteer plants in subsequent cropping cycles.

The domestication of *Oryza sativa L.* reduced natural seed dispersal mechanisms such as seed shattering, a trait that is more pronounced in wild rice species. In wild populations, seed shattering allows grains to detach and fall to the soil, enabling natural reseeding. However, cultivated rice varieties were selected to minimize shattering in order to reduce grain loss during harvest (Science Direct, 1989, #).

The System of Rice Intensification (SRI) emphasizes careful seed management, reduced seed density, and improved soil biological activity. Although SRI does not really rely on natural regeneration as a primary propagation method, it promotes soil health and root development, which can enhance the conditions under which seeds germinate and establish (Regeneration, n.d.).

4.2 Vegetative regeneration

Vegetative regeneration in *Oryza sativa L.* is primarily studied in laboratory, not field, conditions. Plant regeneration can be achieved from primarily callus derived from immature embryos cultured in vitro. In this process, immature embryos are placed on culture media that induce callus (undifferentiated cell mass) formation, this calli are then stimulated to produce shoots and subsequent whole parts when given the appropriate combination of hormones such as auxins and cytokinins (Velez, 1996-1997, #).

The study also explains that the success of regeneration depends on factors such as the type of rice (genotype) and the composition of the culture medium. Some indica rice varieties respond better than others, and adjusting hormone concentrations can significantly improve regeneration

rates. This type of regeneration is important for plant breeding and genetic studies, particularly in tissue culture, genetic transformation, and conservation research, even though it is not a propagation method used in field agriculture (Velez, 1996-1997, #).

4.3 Nursery propagation

Nursery propagation is an important step in rice cultivation and production when farmers use the transplanting method. Instead of planting seeds directly in the main field, seeds are first grown in a different nursery area. This gives the young rice plants a protected and controlled environment during their early growth, which helps them become stronger before being moved to the field (Ministry of Agriculture, n.d.)

According to the Rice Production Training Manual, the nursery should be located near a reliable water source and on level ground to allow proper irrigation and drainage. The soil needs to be fertile, well prepared, and free of weeds. Seeds are usually soaked before sowing to improve germination. After sowing, the nursery must be kept moist, but not flooded, to prevent seed rot and to support healthy seedling development.

The Springer chapter on rice nursery techniques explains that seedlings are generally ready for transplanting after about 20–30 days, depending on the variety and environmental conditions. By this stage, seedlings have developed several leaves and a stronger root system, which helps them survive the stress of transplanting. Proper spacing in the nursery is also important because overcrowding can weaken seedlings and reduce their quality (Springer Nature, 2022, #).

There are different types of nursery systems, including wet-bed nurseries and dry-bed nurseries. Wet-bed nurseries are more common in irrigated systems, while dry-bed nurseries are often used in rainfed areas. Good nursery management — such as regular watering, weed control, and protection from pests — ensures uniform and healthy seedlings, which directly influences crop performance and final yield after transplanting.

4.4 Cuttings

Propagation through cuttings is not commonly used in the cultivation of *Oryza sativa* L. Rice is an annual cereal crop that is primarily propagated by seeds rather than by vegetative plant parts such as stems or leaves. Farmers normally establish rice crops either by sowing seeds directly in the field or by growing seedlings in nurseries and later transplanting them into flooded or prepared paddies (FAO & Bienvenido, 1993, #).

Unlike many perennial crops that can regenerate from stem cuttings, rice plants do not easily produce new plants from detached vegetative parts under normal agricultural conditions. Because of this biological characteristic, propagation by cuttings is not considered a practical or efficient technique for rice production. Instead, seed propagation ensures uniform crop establishment and allows farmers to maintain desired varieties with predictable growth and yield characteristics (IRRI, n.d.).

Although cuttings are not used in traditional rice farming, vegetative regeneration may occur in laboratory settings through tissue culture techniques. These methods allow researchers to regenerate whole rice plants from small pieces of plant tissue under controlled conditions, which is useful for plant breeding and genetic research. However, these techniques are used mainly in scientific research rather than in field cultivation (IRRI, n.d.).

4.5 Plantings

Planting is one of the most important stages in the cultivation of *Oryza sativa* L. because it determines how well the crop will establish and develop throughout the growing season. Rice can be planted using two main methods: direct seeding and transplanting seedlings from a nursery. The method used often depends on factors such as water availability, labor resources, and the type of farming system.

In direct seeding, rice seeds are sown directly into the prepared field. This can be done by broadcasting seeds over the soil surface or by planting them in rows using manual or mechanical seeders. Direct seeding generally requires less labor than transplanting and is increasingly used in modern rice farming systems. However, this method can lead to greater weed competition since the seedlings must establish themselves in the field without the early protection that nursery propagation provides.

The second method, transplanting, involves moving young seedlings from a nursery into the main field once they have developed several leaves and a stronger root system. This technique allows farmers to select healthy seedlings and plant them at regular spacing, which improves plant growth and resource use. Transplanting also helps control weeds more effectively and can lead to better crop establishment, especially in irrigated rice systems.

Proper planting practices—including appropriate spacing, planting depth, and timing—are essential for ensuring uniform crop growth. When rice plants are spaced correctly, they can develop stronger root systems, capture more sunlight, and use water and nutrients more

efficiently. As a result, good planting practices play a major role in achieving stable yields and maintaining productive rice fields (IRRI, n.d.).

4.6 Management of pests and diseases

The management of pests and diseases in *Oryza sativa L.* is a critical component of successful rice production, as biotic stresses can significantly reduce both yield and grain quality. Effective management is based on an integrated approach, combining biological, cultural, and agronomic practices to maintain crop health while minimizing environmental impact.

A central concept in modern rice agriculture is Integrated Pest Management (IPM), promoted by organizations such as the Food and Agriculture Organization. IPM focuses on preventing pest outbreaks through ecosystem-based strategies rather than relying solely on chemical pesticides. This includes maintaining biodiversity in rice fields, which supports natural enemies of pests such as predators and parasitoids (FAO, n.d.).

One of the most effective preventive measures is the use of resistant rice varieties, which are genetically developed to withstand common pests like planthoppers and diseases such as rice blast (*Magnaporthe oryzae*). According to IRRI, resistant varieties reduce crop vulnerability and limit the need for chemical interventions. In addition, balanced fertilization, particularly nitrogen management, is essential, as excessive nitrogen can increase susceptibility to pests and diseases (IRRI, n.d.).

Field monitoring and early detection are also key components of pest and disease management. Regular observation allows farmers to identify early symptoms—such as leaf lesions, discoloration, or insect presence—and take timely action before infestations spread. This aligns with FAO guidelines, which emphasize decision-making based on field thresholds rather than routine pesticide application.

Cultural practices further support pest and disease control. These include crop rotation, proper spacing, removal of infected plant residues, and weed management, all of which reduce the survival and spread of pathogens and insect populations between growing seasons. Water management also plays a role, as flooded conditions can suppress certain weeds but may favor others, requiring careful regulation.

4.7 Pest and disease control

Pest and disease control in *Oryza sativa L.* refers to the specific actions taken to reduce pest populations and disease incidence once they reach harmful levels. Unlike general management, which focuses on prevention, control methods are applied when there is a direct threat to crop yield. Modern rice production relies on a combination of biological, cultural, mechanical, and chemical control methods, all integrated within an IPM framework.

One of the most important approaches is biological control, which uses natural enemies such as predators, parasitoids, and pathogens to suppress pest populations. Studies show that organisms like spiders, beetles, and parasitic insects play a key role in reducing pest numbers naturally, helping maintain ecological balance in rice fields. In addition, conserving these beneficial organisms is essential, as they reduce the need for chemical inputs (Hajjar et al., 2023).

Cultural and mechanical control methods are also widely used. These include removing infected plant parts, handpicking insect egg masses, using traps (such as light or pheromone traps), and adjusting planting times to avoid peak pest populations. Research demonstrates that practices like weed removal, proper seed selection, and field sanitation significantly reduce pest habitats and disease spread. These methods are especially important in sustainable agriculture because they are low-cost and environmentally friendly (*Frontiers*, 2016).

Chemical control is considered a last-resort method and is used when pest populations exceed economic thresholds. This involves applying insecticides, fungicides, or bactericides in a targeted and controlled manner. Scientific studies emphasize that pesticides should only be used when necessary, as excessive use can lead to resistance in pests and negative environmental effects. Proper timing and dosage are critical to ensure effectiveness while minimizing harm (PeerJ, 2023).

Recent research also highlights the importance of combining control strategies. For example, integrating biological control (natural enemies) with selective chemical use and practices like removing infected plants (roguing) has been shown to significantly reduce disease spread in rice systems. This confirms that no single method is sufficient on its own; instead, a coordinated approach is necessary (Scientific Reports, 2025).

4.8 Cultivation

The cultivation of *Oryza sativa* L. involves a series of field practices that support plant growth from planting to harvest. These practices include land preparation, water management, weed control, and nutrient management, all of which are essential for achieving good yields.

One of the first steps in cultivation is land preparation. Fields are usually plowed and leveled to create a uniform surface. In many rice systems, especially irrigated ones, the soil is also puddled, meaning it is mixed with water to form a soft, muddy layer. This helps reduce water loss, improves seedling establishment, and limits weed growth (FAO & Bienvenido, 1993, #).

Water management is a key factor in rice cultivation because rice is typically grown under flooded conditions. Maintaining a shallow layer of water helps suppress weeds and provides a stable environment for plant growth. However, water levels must be carefully controlled throughout the growing cycle. For example, fields may be drained temporarily to strengthen roots or before harvest to allow the soil to dry

Weed control is also important, especially during the early stages of growth when rice plants are still developing. Weeds compete with rice for nutrients, light, and water, so they must be controlled through flooding, manual removal, or herbicides when necessary. Good crop establishment and proper spacing can also help reduce weed competition (FAO & Bienvenido, 1993, #).

Another important aspect of cultivation is nutrient management. Rice plants require essential nutrients such as nitrogen, phosphorus, and potassium for proper growth. Nitrogen is especially important for leaf development, but it must be applied carefully, since too much nitrogen can make plants more vulnerable to pests and diseases.

Overall, successful rice cultivation depends on the proper coordination of soil preparation, water control, weed management, and nutrient supply. When these practices are managed effectively, they create the right conditions for healthy plant growth and high productivity.

4.9 Fertilizing

Fertilizing is a critical component in the cultivation of *Oryza sativa* L., as it ensures that rice plants receive the essential nutrients required for healthy growth and high yields. Rice production systems often depend on the addition of fertilizers because many soils, especially in intensively cultivated areas, do not naturally supply sufficient nutrients throughout the growing season.

The most important nutrients for rice are nitrogen (N), phosphorus (P), and potassium (K). Nitrogen is particularly important because it promotes leaf and stem growth, which directly affects photosynthesis and overall plant development. However, excessive nitrogen application can make rice plants more susceptible to pests, diseases, and lodging (falling over), so it must be carefully managed.

Phosphorus plays a key role in root development and early plant growth, helping seedlings establish strong root systems. Potassium, on the other hand, contributes to overall plant health, improving resistance to stress, diseases, and environmental conditions such as drought or salinity. A balanced application of these nutrients is essential to achieve optimal crop performance.

Fertilizers can be applied in different ways and at different stages of the crop cycle. A common practice is to apply part of the nitrogen at planting or transplanting, followed by additional applications during key growth stages such as tillering and panicle initiation. This method, known as split application, improves nutrient use efficiency and reduces losses due to leaching or volatilization (FAO & Bienvenido, 1993, #).

In addition to chemical fertilizers, farmers may also use organic matter such as compost or manure to improve soil fertility and structure. Organic inputs help increase soil organic matter, enhance microbial activity, and improve water retention, which benefits long-term soil health.

4.10 Growth stages

The growth stages of *Oryza sativa* L. describe the developmental phases that the plant undergoes from germination to maturity. Rice growth is generally divided into three main stages: vegetative, reproductive, and ripening (Rice knowledge Bank, n.d.).

The vegetative stage begins with seed germination and continues through seedling establishment and tillering. During this phase, the plant develops leaves, stems, and roots. One of the most important processes in this stage is tillering, where the plant produces multiple shoots that can later form grain-bearing panicles. Proper nutrient supply, especially nitrogen, is crucial at this stage to support strong vegetative growth.

The reproductive stage starts with panicle initiation, when the plant begins to form the flowering structure inside the stem. This is followed by booting, heading, and flowering. During this phase, the plant is highly sensitive to environmental stress, particularly water shortages and extreme temperatures, which can significantly affect grain formation and yield. Adequate water and nutrient availability are therefore essential.

The final phase is the ripening stage, which includes grain filling and maturation. During this stage, the plant directs energy toward developing and filling the grains with starch. Leaves may begin to yellow as the plant approaches maturity. Water levels are often reduced or fields are drained to allow the crop to dry and prepare for harvest. (Rice knowledge Bank, n.d.).

4.11 Fruiting

Fruiting in *Oryza sativa* L. is the stage where fertilized flowers develop into grains. In rice, the fruit is a caryopsis, meaning the seed and fruit wall are fused into a single structure. This process begins after flowering, when spikelets start forming grains through grain filling. During this stage, sugars produced by photosynthesis are transported to the grains and converted into starch. Grain development passes through the milk stage, dough stage, and finally maturity, when the grain becomes hard and fully formed (FAO & Bienvenido, 1993, #).

Fruiting is highly sensitive to environmental conditions. Adequate water, nutrients, and stable temperatures are essential, as stress during this phase can lead to empty or poorly filled grains (Food and Agriculture Organization). In summary, fruiting is a critical stage that determines final yield, as it directly affects the number and quality of grains produced (FAO & Bienvenido, 1993).

4.12 Harvesting

Harvesting of *Oryza sativa* L. is carried out when the grains reach full maturity and optimal quality. This usually occurs when about 80–85% of the grains on the panicle are golden yellow, indicating that grain filling is complete (Rice knowledge Bank, n.d.).

At this stage, the moisture content of the grain is typically around 20–25%, which is suitable for harvesting. If harvested too early, grains may be immature and have lower quality; if harvested too late, there is a higher risk of grain shattering and losses in the field.

Harvesting can be done manually, using sickles, or mechanically with combine harvesters. After harvesting, the rice must be threshed to separate the grains from the plant and then dried to reduce moisture content for safe storage (FAO & Bienvenido, 1993, #).

4.13 Pruning - re-planting

In Oryza sativa L. pruning is generally not required because rice is an annual plant that completes its life cycle in one season. Replanting is more important and usually occurs through transplanting, where seedlings grown in nurseries are moved to the field. This improves spacing and early growth

5.0 Economic importance and uses

5.1 Global production and trade

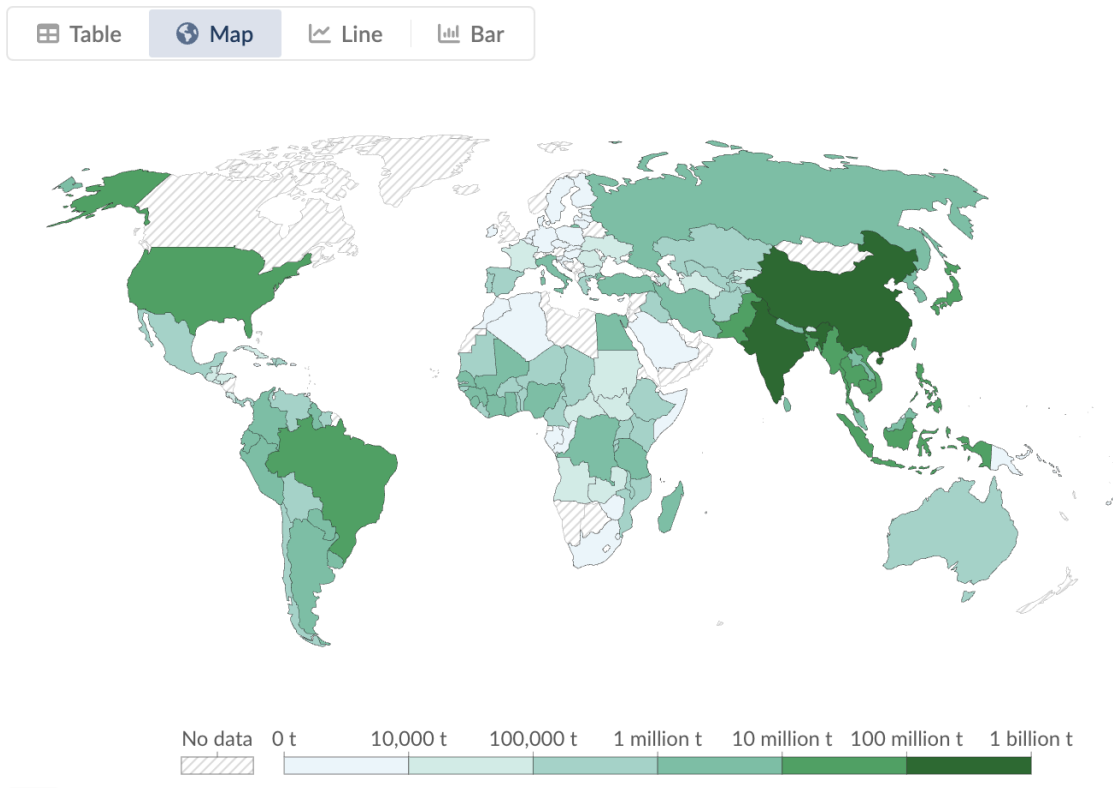
Oryza sativa L. is one of the most important staple crops in the world, providing a primary source of calories for more than half of the global population, particularly in Asia (Food and Agriculture Organization, 2020). Global rice production exceeds 750 million metric tons annually, with more than 90% of this production occurring in Asia, as seen in **Figure 1** (Our World Data, 2024).

Figure 1

Rice production in 2024 (Our World Data, 2024)

Rice production, 2024

Our World
in Data



The leading producers are China, India, Indonesia, Bangladesh, and Vietnam, which together account for the majority of global output. China and India alone contribute more than half of

total production, reflecting the geographic concentration of rice cultivation (Our World Data, 2024).

Rice is also a major commodity in international trade, although only about 10-20% of global production is traded globally because most rice is consumed domestically. Major exporters include India, Thailand, Vietnam, Pakistan and the United States, while major importers include countries in Africa and the Middle East where local production is insufficient to meet demand. The global rice market is valued at hundreds of billions of dollars annually, making it one of the most economically significant agricultural commodities in the world (FAO, 2020).

5.2 Regional and national importance

At the regional level, rice plays a crucial role in economic development and rural livelihoods. In Latin America, countries such as Brazil, Colombia, and Peru cultivate rice for both domestic consumption and regional trade. In Colombia, rice is one of the most important cereal crops, contributing significantly to national food security and the agricultural economy.

Rice production generates employment across multiple stages of the value chain, including cultivation, harvesting, processing, and commercialization. Many smallholders farmers depend on rice as a primary source of income, and the crop supports agro industrial sectors such as milling and packaging. In addition, rice serves both as a subsistence and commercial crop, allowing farmers to ensure household food supply while also participating in local markets (FAO, 2020).

5.3 Market structure and distribution

The rice market is characterized by a strong emphasis on domestic consumption, with governments often regulating supply through policies such as subsidies, price controls and strategic reserves to maintain food security. Internationally, the rice trade is relatively concentrated among a limited number of exporting countries, which means that production or policy changes in these countries can significantly influence global prices.

Rice is marketed in several forms, including paddy rice, milled white rice, brown rice, and parboiled rice. Market value is influenced by quality characteristics such as grain size, aroma, and texture, with premium varieties commanding higher prices (FAO, 2020).

5.4 Value-added products and processing

Although rice is widely consumed as a whole grain, it is also processed into a variety of value added products. The primary processing step is milling, which converts paddy rice into edible white rice by removing the husk and bran layers.

By-products of milling include rice bran and rice husk, both of which have important economic uses. Rice bran is used to produce rice bran oil, while rice husk can be used as fuel, animal bedding or raw material for construction and energy production.

Rice is also processed into products such as rice flour, noodles, breakfast cereals, snacks, and beverages, expanding its role in the food industry. In addition, rice derivatives are used in non food industries, including pharmaceuticals and cosmetics, where rice starch serves as a functional ingredient (FAO & Bienvenido, 1993).

5.5 Economic significance

The economic importance of *Oryza sativa L.* extends beyond production volume, as it is a key driver for rural development, employment, and food security. Millions of farmers worldwide depend on rice cultivation for their livelihoods, particularly in developing countries

Because of its central role in global nutrition, rice is considered a strategic commodity. Governments invest in research, irrigation systems and improved crop varieties to increase productivity and ensure stable supply (FAO, 2020).

Overall, rice is not only a staple food but also a critical economic asset at local, regional, and global levels, with extensive production, diverse application, and a central role in global trade and food systems (Our World Data, 2024).

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