

Aloe vera (*Aloe barbadensis* Miller)

Monograph



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Introduction	3
2.0 Agroecology	4
2.1 Taxonomy, botanical authority	4
2.2 Fossil record of Aloe vera	12
2.3 Origin and current distribution of Aloe vera	14
2.4 Ecoregion of Aloe vera	17
2.5 Climate Preferences of Aloe vera	18
2.6 Soils and geology of Aloe vera	21
2.7 Water requirements of Aloe vera	25
2.8 Light and temperature regimens of Aloe vera	28
3.0 Biology	32
3.1 Chromosome Complement	32
3.2 Life Cycle and Phenology	34
3.2.1 Life Cycle	34
3.2.2 Phenology	35
3.3 Anatomy and Growth Habits	36
3.3.1 Anatomy	36
3.3.2 Growth Habits	38
3.4 Reproductive Biology	39
3.4.1 Sexual Reproduction	40
3.4.2 Asexual Reproduction	40
3.5 Ecophysiology	41
4.0 Propagation and management	45
4.1 Natural Regeneration	45
4.2 Nursery Propagation	46
4.2.1 Propagation from seed	49
4.2.2 Vegetative propagation	51
4.3 Planting	54
4.4 Tending	56
4.5 Fruiting	58
4.6 Pest and disease control	60
5.0 Importance, markets, and uses	62
5.1 Global and Regional Market Overview	63
5.1.1 Major Producing Countries	64
5.2 Production and Economic Value	66
5.3 Food Products Derived from Aloe vera	68
5.3.1 Fresh Gel	69
5.3.2 Juice and Beverages	69
5.4 Cosmetic and Medicinal Products	69
5.4.1 Cosmetic Products	70
5.4.2 Medical and Pharmaceutical Products	70
5.5 Value to Local Economies	71
References	73

Introduction

Aloe vera is a globally cultivated succulent plant whose biological importance and adaptability make it an important subject of study. It is widely used in medicinal, cosmetic, and agricultural applications, and has been valued for centuries in both traditional and modern practices. Its ability to survive in arid environments shows its significance as a resilient and sustainable crop, especially in regions affected by water scarcity.

The selection of *Aloe vera* for this monograph is based on both its scientific relevance and its presence in everyday life. This plant was chosen because it represents a connection between biological processes and real-world applications, particularly in areas such as health, agriculture, and industry. Its widespread use, combined with its unique adaptations to extreme environmental conditions, makes it a meaningful and interesting subject of study.

This monograph is organized into several chapters, each addressing a different aspect of *Aloe vera*. Chapter 2 focuses on the plant's ecology, including its taxonomy, origin, distribution, climate preferences, and soil and geological requirements. Chapter 3 examines its biological characteristics, such as chromosome complement, anatomy, and ecophysiology. Chapter 4 explores propagation and management practices, including nursery propagation, planting, tending, and pest and disease control. Finally, Chapter 5 analyzes the economic importance of *Aloe vera*, highlighting its applications in food, cosmetic, and pharmaceutical industries.

Together, these factors provide a comprehensive overview of the biological, environmental, and economic importance of *Aloe vera*.

2.0 Agroecology

2.1 Taxonomy, botanical authority

Aloe vera is classified within the plant Kingdom and follows the standard hierarchy of Botanical Taxonomy, as shown in **Table 1**. It belongs to the Kingdom Plantae, Division Tracheophyta, Class Liliopsida (monocots), Order Asparagales, and Family Asphodelaceae (Royal Botanic Gardens, Kew, n.d.). Within this framework, it is placed in the Genus *Aloe*, with the specific species identified as *Aloe vera* (L.) Burm. f. This classification highlights its identity as a vascular, monocotyledonous, succulent plant with unique adaptations to dry environments, providing the foundation for a deeper exploration of each rank. The authority (L.) Burm. f. credits Carl Linnaeus, who first described the plant as *Aloe perfoliata* var. *vera* in *Species Plantarum* (1753), and Nicolaas Laurens Burman, who later established the accepted name *Aloe vera* in *Flora Indica* (1768) (United States Department of Agriculture, 2024).

Table 1

Taxonomic hierarchy of *Aloe vera*

TAXONOMIC RANK	TAXON NAME (authority)
Kingdom	<i>Plantae</i>
Division	<i>Tracheophyta</i>
Class	<i>Liliopsida</i>
Order	<i>Asparagales</i>
Family	<i>Asphodelaceae</i>
Genus	<i>Aloe</i>
Species	<i>Aloe vera</i>

Note: This table summarizes the taxonomic of *Aloe vera*, beginning with the classification in the Kingdom and going down to its specific Species. It shows the main ranks along with the taxon name. This table is adapted from the data collected from the USDA Plants Database (United States Department of Agriculture, 2024)

Kingdom

Because *Aloe vera* belongs to the Kingdom Plantae, it shares the fundamental features of plants, such as being photosynthetic and cell walls made of cellulose. *Aloe vera* belongs to Plantae because it uses chlorophyll to convert the sunlight into energy, stores starch and it exhibits all the typical traits of vascular land plants. *Aloe vera* is part of Plantae since it produces its own food through photosynthesis, has cellulose-based cell walls, and stores energy as starch (United States

Department of Agriculture, 2024). Being in Plantae means *Aloe vera* functions as a green plant with chlorophyll, energy storage in starch, and the structural traits that define land plants (Surjushe et al., 2008). Within this Kingdom, it is further classified into the division Magnoliophyta, which includes all flowering plants (United States Department of Agriculture, 2024).

Division

As a member of Magnoliophyta, *Aloe vera* is part of the flowering plants, and this leads directly into its classification within the Class Liliopsida, also known as monocots. The Division Tracheophyta, also known as vascular plants, is characterized by specialized tissue "xylem and phloem" that transport water, minerals and sugars throughout the plant (Royal Botanic Gardens, Kew, n.d.) *Aloe vera* fits within this group because it has vascular bundles running through its succulent leaves that distribute water and nutrients efficiently, an adaptation that allows it to thrive in arid environments. *Aloe vera* belongs to Tracheophyta, since its vascular tissues move essential resources, supporting survival in dry climates (United States Department of Agriculture, 2024).

Being a vascular plant, *Aloe vera* relies on xylem and phloem to carry water and food, a trait that connects it to other flowering plants within Magnoliophyta (United States Department of Agriculture, 2024).

Class

Being in the Liliopsida (monocot), *Aloe vera* falls into the order Asparagales, a group that contains many monocot plants adapted to dry or specialized environments. Liliopsida, includes

plants that have a single seed leaf called cotyledon, parallel veined leaves, and flower parts typically in multiple of three (Royal Botanic Gardens, Kew, n.d.) *Aloe vera* demonstrates these features through its long, straplike leaves with parallel venation and its flowers, which appear in clusters with parts arranged in threes. Photo number 1 shows a close up of a parallel veined leaf, a very common characteristic of monocots like *Aloe vera*. *Aloe vera* is part of the monocot group because its floral organs occur in sets of three, and its leaves grow with veins running side by side (United States Department of Agriculture, 2024). As a Liliopsida, *Aloe vera* shares the defining trait of a single cotyledon in its seeds, which distinguishes it from dicots and confirms its place among monocots (United States Department of Agriculture, 2024).

Order

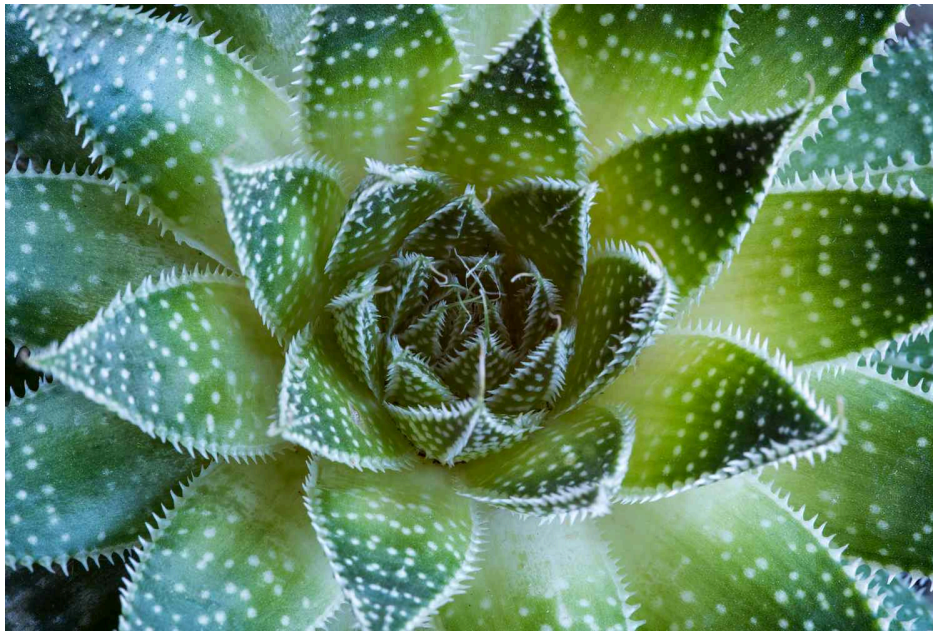
Within Asparagales, it belongs to the family Asphodelaceae, which is characterized by succulent plants well suited to arid conditions. This family connection highlights the adaptations that allows *Aloe vera* to store water and survive drought (CHASE & REVEAL, 2009) *Aloe vera* belongs to this order because of its succulent growth form and production of compounds such as aloin and acemannan, substances with ecological and medicinal roles. *Aloe vera* is placed in Asparagales since members of this group often display specialized tissues for conserving moisture in dry climates (CHASE & REVEAL, 2009). Additionally, it fits this order because its chemical compounds, like acemannan, serve both as a defense mechanism and as a trait typical of *Asphodelaceae* plants (Royal Botanic Gardens, Kew, n.d).

Family

The Asphodelaceae Family contains the Genus *Aloe*, a diverse group of plants known for their rosettes of fleshy leaves and medicinal properties (Royal Botanic Gardens, Kew, n.d.). *Aloe vera* belongs to this Genus because it shares the characteristics of morphology and also medicinal gel properties that distinguish aloes from other succulent groups. **Figure 1** shows a rosette of fleshy, pointed leaves, a growth form typical of members of the Asphodelaceae Family. Members of Asphodelaceae are generally succulents that retain water in their leaves, which explains *Aloe vera*'s thick, gel-filled foliage (CHASE & REVEAL, 2009). *Aloe vera* also fits this family because, like many of its relatives, it produces bioactive compounds that are used in traditional medicine (Surjushe et al., 2008).

Figure 1

Rosette formation of *Aloe vera*



Note: This is a picture from (McIntosh, 2025) It shows the rosette formation of *Aloe vera*, typical of the Asphodelaceae family, which helps the plant store water in dry environments.

Genus

Within the Genus *Aloe*, *Aloe vera* stands out as the most widely cultivated and studied species, recognized for its thick leaves filled with healing gel. The Genus *Aloe* consists of over 500 species, distributed mainly in Africa and Arabia, recognized for their thick, fresh leaves, mucilaginous gel and toothed margins (CHASE & REVEAL, 2009) *Aloe vera* belongs to this Genus because it shares the characteristics of morphology and medicinal gel properties that distinguish aloes from other succulent plant groups. **Figure 2** shows the *Aloe vera* plant itself, with its characteristic thick, pointed leaves arranged in a rosette, directly representing the Genus *Aloe*. Like other aloes, *Aloe vera* has spiny margins and stores water in its leaves, traits that are essential for surviving in dry regions (United States Department of Agriculture, 2024). Additionally, *Aloe vera* fits into this Genus because its gel contains secondary metabolites similar to those found across other *Aloe* species, reinforcing its botanical placement (Surjushe et al., 2008).

Figure 2

Mature *Aloe vera*



Note: This is an image from (Leech, 2020). It shows a mature *Aloe vera* plant, classified at the Species level for its gray-green, fleshy leaves and medicinal gel.

Species

Aloe Vera (L.) Burm. f. At the Species level, *Aloe vera* is a stemless perennial succulent with a lance shape, grayish and green leaves that can reach up to 50 centimeters in length (United States Department of Agriculture, 2024). The inner gel of its leaves contains compounds with soothing, moisturizing and wound healing properties, which explains its widespread use in traditional medicine, cosmetics and modern pharmaceuticals (Surjushe et al., 2008). **Figure 3** provides a close up view of the leaf detail, highlighting the gel filled structure that is unique to *Aloe vera* and central to its medicinal uses. This species is further identified by its rosette arrangement and the absence of a visible stem, features that separate it from many other aloes (Surjushe et al., 2008). Moreover, the biochemical profile of *Aloe vera* gel, rich in polysaccharides like

acemannan, is a defining trait at the species level that supports its medicinal reputation (United States Department of Agriculture, 2024).

Figure 3

Inner gel of *Aloe vera*



Note: This image is from (Ralls, 2019). This is a cut of an *Aloe vera* leaf with its inner gel exposed, a defining characteristic of the Genus *Aloe* and the Species *Aloe vera*, widely used for medicinal purposes.

2.2 Fossil record of *Aloe vera*

The fossil record of the *Aloe* genus is limited, which is common among soft-tissue succulent plants that do not fossilize easily. Succulents rarely leave preserved remains because their tissues decay quickly and lack woody structures that typically fossilize (CHASE & REVEAL, 2009).

However, researchers study the fossil record of the *Asphodelaceae* family and the broader Asparagales in order to understand the evolutionary history of *Aloe* (Royal Botanic Gardens, Kew, n.d). Fossil pollen grains and molecular clock data suggest that the ancestors of *Aloe* likely

originated in Southern Africa approximately 16-20 million years ago, during a period when the African climate was becoming more arid (CHASE & REVEAL, 2009). As conditions became drier, *Aloe* species evolved water-storing leaves and protective leaf spines to prevent water loss and herbivory, adaptations still seen in *Aloe vera* today. **Figure 4** illustrates an example of an early ancestor of the *Aloe* genus, showing features consistent with adaptation to arid environments.

These ancestral plants already showed xerophytic adaptations, such as thick tissues for water storage, which later become defining traits of *Aloe* species (Surjushe et al., 2008). Molecular phylogenetic studies show that the *Aloe* genus diverged in Africa, evolving in response to climate shifts towards hotter and drier environments during the Miocene (CHASE & REVEAL, 2009).

Consequently, while we lack fossils of *Aloe vera* itself, genetic and paleobotanical evidence strongly supports an ancient lineage adapted for survival in arid regions.

Figure 4

Early ancestor of the *Aloe* genus



Note: This image is from (*Oldest Completely Preserved Lily Discovered*, 2019). This fossil represents an early ancestor of the *Aloe* genus, showing features like parallel veins and thick leaf tissue that suggest adaptation to arid environments.

2.3 Origin and current distribution of *Aloe vera*

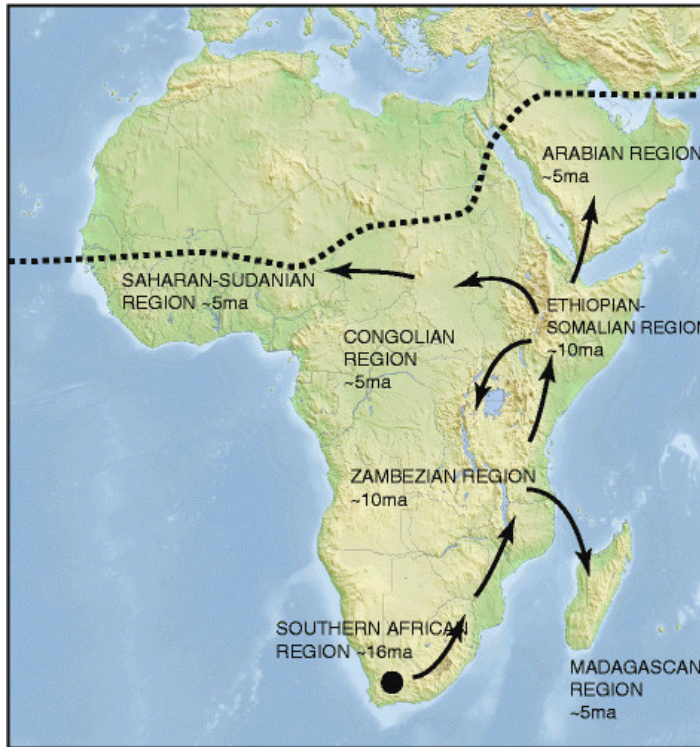
The exact origin of *Aloe vera* is not completely certain, but most scientific research suggests that it likely originated in the Arabian Peninsula, particularly in regions that today include Yemen, Oman, and Saudi Arabia. These areas provide the dry, hot climate that the plant may have appeared earlier in northeastern Africa, especially in Sudan and Ethiopia, before spreading north and east transported and grown by humans for thousands of years, tracing its origin through

natural distribution alone is difficult. However, genetic studies show strong links between *Aloe vera* and wild *Aloe* species from the Horn of Africa, which supports the African origin theory.

Figure 5 illustrates the proposed origin and dispersal of the Aloe genus, showing its spread from Africa to the Arabian Peninsula and surrounding regions. Historically, *Aloe veras* was valued very early for its healing properties. In Ancient Egypt, it was known as the “plant of immortality” and used in both medicine and burial practices (ESHUN & HE, 2004). Egyptian queens like Cleopatra and Nefertiti are believed to have use Aloe gel as part of the skin care routines, From Egypt, the plant spread to the Mediterranean region, where the Greeks and Romans also used it for treating wounds and burns. Later, with the development of maritime trade, *Aloe vera* traveled to India, China, and Southeast Asia, where it became part of traditional herbal medicine systems. By the 16th century, Spanish and Portuguese sailors carried the plant to the Americas, where it adapted very successfully to warm climates (ESHUN & HE, 2004).

Figure 5

Proposed origin



Note: This image is from (Grace et al., 2015). It shows the proposed origin of the *Aloe* genus in Africa and its later dispersal into the Arabian Peninsula and neighboring regions, supporting the hypothesis that *Aloe vera* originated in the Arabian Peninsula and later spread through human cultivation.

Today, *Aloe vera* is cultivated in many tropical and subtropical regions around the world. It is commonly grown in North Africa, the Canary Islands, Southern Spain, Cape Verde, Mexico, India, China, Colombia, and the southern United States. While *Aloe vera* is not usually found growing wild, it thrives in controlled agricultural systems because it needs strong sunlight and well-drained soil. The plant has become especially important in the global cosmetic, pharmaceutical, and food industries, which use Aloe gel for creams, drinks, skin treatments, and health supplements (Hamman, 2008).

2.4 Ecoregion of *Aloe vera*

Aloe vera naturally occurs in arid and semi arid regions of the world, typically in desert margins, dry savannas, and rocky slopes where water is scarce and soils are sandy or well-drained. It thrives in open, sunny environments rather than shaded understory areas, which reflects its environments rather than shaded understory areas, which shows its adaptation to high solar radiation and limited moisture (Carter et al., 2026) In the wild, *Aloe vera* and its close relatives are often found on flat plains or gentle hillside where rainwater can drain quickly, preventing root rot. These conditions promote the development of its succulent leaves, which functions as water storage organs, allowing the plant to survive prolonged dry periods.

Figure 6 shows *Aloe vera* growing in a native arid habitat, illustrating the environmental conditions in which the species naturally thrives. Although *Aloe vera* is now largely cultivated, studies of wild relatives in eastern and Southern Africa show that the genus *Aloe* typically grows in habitats with rocky or sandy soils and minimal canopy cover, indicating it evolved as a sun loving xerophyte (Isager Ahl et al., 2023)

Figure 6

Native habitat in the Arabian Peninsula



Note: This image is from (Foote, 2015). It shows an *Aloe vera* plant growing in an arid, sun-exposed environment typical of its native habitat in the Arabian Peninsula and northeastern Africa. The thick, fleshy leaves and clustered rosette growth form illustrate its adaptation to hot, dry climates and full sunlight.

2.5 Climate Preferences of *Aloe vera*

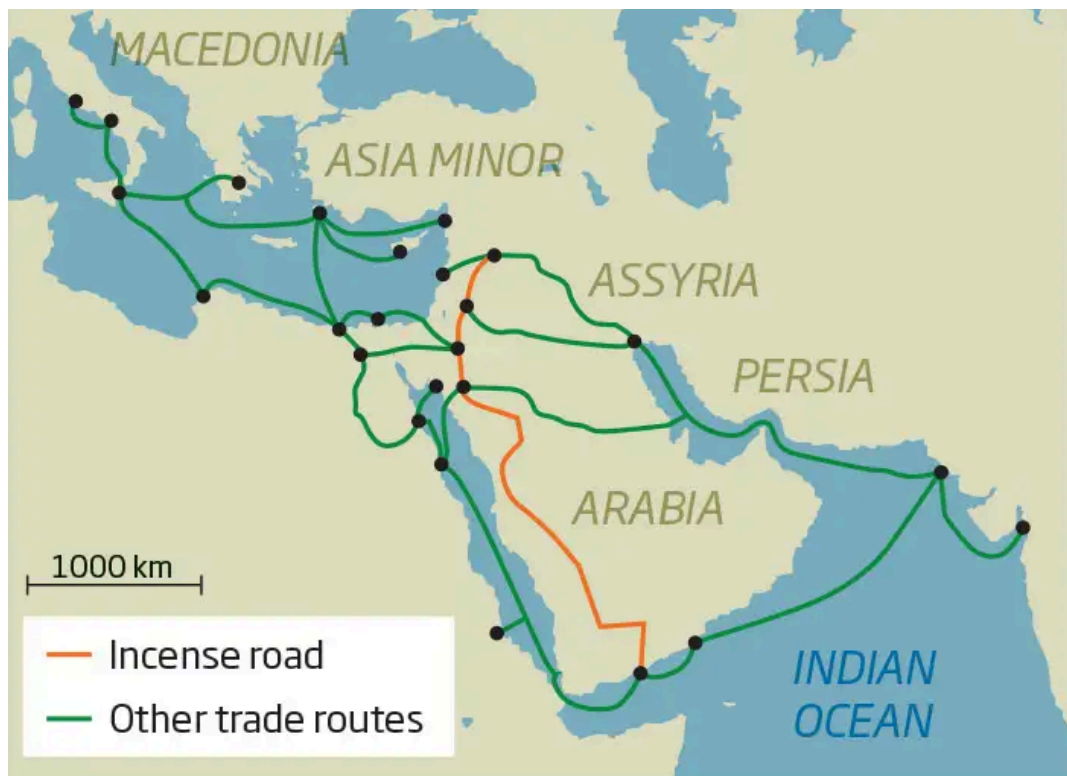
Aloe vera is adapted to hot, dry climates with seasonal rainfall and high sunlight exposure. It prefers temperatures between 20°C and 30°C, although mature plants can withstand brief drops to 5°C and highs above 40°C (Hamman, 2008). The plant performs best in areas with annual rainfall between 300-1000 mm, distributed irregularly, allowing dry seasons during which it can store water. These climatic features correspond to semi-arid and subtropical regions, which include much of Africa, the Arabian Peninsula, and parts of India and Mexico where the species is cultivated. **Figure 7** illustrates the historical origin and early dispersal of *Aloe vera* across

regions with suitable climatic conditions. **Figure 8** shows a related Aloe species growing in a semi-arid environment, demonstrating the type of habitat in which Aloe species thrive.

Unlike rainforest plants that depend on constant humidity, *Aloe vera*'s physiology is built for water efficiency, its thick cuticle, reduced stomata, and CAM photosynthesis allow it to minimize water loss during the day and fix carbon at night (ESHUN & HE, 2004). This adaptation helps explain why *Aloe vera* does not grow well in shaded, humid environments; instead, it prospers in open sunlight and well-drained soil conditions.

Figure 7

Origin of *Aloe vera*



Note: This image is from (Pain, 2015) “*How Aloe vera became a global plant.*” It shows the proposed origin of *Aloe vera* in the Arabian Peninsula (modern Yemen and Oman) and its early dispersal across Africa and Asia through ancient trade routes, highlighting the species’ long history of human cultivation and migration.

Figure 8

Aloe dewinteri



Note: This image is from (*Aloe Dewinteri* | *PlantZAfrica*, 2017). It shows *Aloe dewinteri* growing on rocky slopes under full sunlight in Namibia, a typical semi-arid habitat similar to that of *Aloe vera*. The picture illustrates the plant's adaptation to high sunlight exposure and dry, well-drained conditions, characteristic of the natural environments where *Aloe* species occur.

2.6 Soils and geology of *Aloe vera*

Aloe vera naturally occurs in semi-arid and arid regions, where both soil composition and the underlying geology are fundamental to its survival and growth. These, environments, typically located in parts of northeastern Africa and the Arabian Peninsula, are characterized by low rainfall, high solar radiation, and extreme temperature variation (Grace et al., 2015). The soils in these areas are derived from the weathering of igneous and sedimentary rocks, such as basalt, granite, and limestone, resulting in coarse-textured, shallow, and well-drained soils. These physical properties are ideal for *Aloe vera* because they prevent waterlogging and root rot conditions that would be lethal to a succulent species adapted to drought. **Table 2** summarizes

the key geological and soil characteristics that support the growth of *Aloe vera*, including drainage, pH, and mineral composition. **Figure 9** illustrates a typical soil horizon structure found in semi-arid environments, highlighting the layered composition and drainage properties of these soils.

The geological foundation directly influences the soil chemistry. In regions where limestone or calcareous bedrock dominate, the soil tends to be alkaline (pH 7–8.5) and rich in calcium carbonate, which enhances nutrient availability and stabilize soil structure (CHASE & REVEAL, 2009). Conversely, soils formed from granite and sandstone are acidic to neutral and typically nutrient-poor, but they offer superior drainage and aeration, both crucial for *Aloe vera*'s fibrous root system. This geological differences shape the distribution of *Aloe vera* populations, as the plant favors substrates that combine high porosity, low organic matter, and moderated mineral content.

In addition to pH and texture, mineral composition plays a vital role in the plant's physiology. Soils enriched with magnesium and potassium from weathered basalt support the plant's photosynthetic efficiency and osmotic regulation (Surjushe et al., 2008). Trace elements such as iron and magnesium contribute to the chlorophyll production, while low nitrogen levels limit excessive vegetative growth, helping the plant conserve energy and water. *Aloe vera* also demonstrates moderate halotolerance, enabling it to grow in saline or degraded soils, an important adaptive trait for survival in dry coastal or inland deserts (Surjushe et al., 2008)

The interaction between soil and geology thus defines *Aloe vera*'s ecological niche. The rocky terrain provides excellent drainage and prevents competition from larger, deep-rooted plants, while mineral weathering continuously replenishes essential nutrients in the thin topsoil. This delicate balance between geological substrate, soil chemistry, and plant physiology has made *Aloe vera* one of the most successful succulents in semidesert ecosystems. Its evolutionary success can be seen as a direct response of nutrient scarce but mineral-rich soils shaped by ancient geological processes.

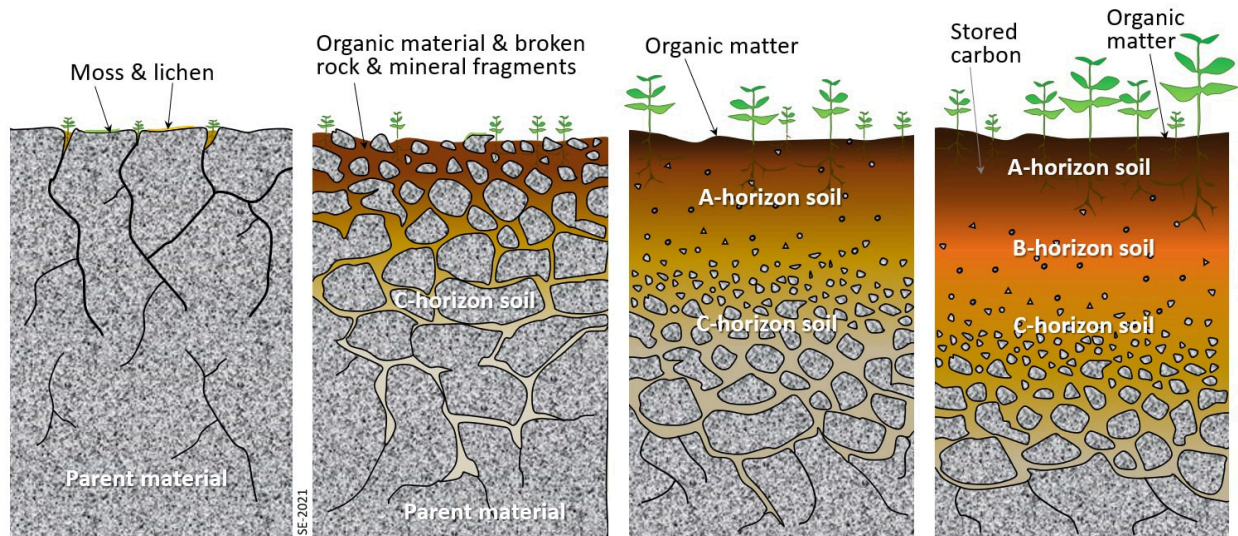
Table 2**Key geological characteristics that support the growth of plant**

CHARACTERISTICS	DESCRIPTION	SCIENTIFIC RELEVANCE TO ALOE VERA
Soil Type	Sandy-loam or light clay-loam, often mixed with coarse sand and gravel.	Promotes rapid drainage and prevents root rot, common in poorly drained soils.
Soil pH	Slightly alkaline (7.0–8.5).	Alkaline soils favor nutrient absorption and are typical of semi-arid environments.
Organic Matter	Low to moderate	Aloe vera is adapted to nutrient-poor soils; excessive organic matter may cause fungal growth.
Porosity and Drainage	High porosity and excellent drainage due to coarse particles and loose structure.	Essential for preventing waterlogging and maintaining root oxygenation.
Salinity Tolerance	Moderate; tolerates saline and calcareous soils.	Reflects adaptation to arid coastal and desert ecosystems.
Geological Substrate	Derived from volcanic, limestone, or sandstone parent material.	Provides essential minerals like calcium, magnesium, and potassium that support growth.
Soil Depth	Shallow to moderately deep (30–60 cm).	Allows roots to anchor while reducing excess water retention.
Texture	Gritty and friable with visible mineral particles (quartz, basalt fragments).	Improves aeration and root expansion in dry soils.

Note: This table is adapted from (Surjushe et al., 2008). Summarizes the key soil and geological characteristics that support the growth of plant. It shows how soil texture, drainage, and mineral composition influence the plant's adaptation to arid environments and its nutrient absorption.

Figure 9

Typical soil horizon structure in semi-arid soils



Note: This image is from (*ESS Subtopic 5.1: Soils*, 2017). It depicts a shallow, sandy-loam soil profile typical of semi-arid regions. The high porosity and mineral fragments from limestone and quartz provide excellent drainage and nutrient availability, conditions ideal for *Aloe vera* growth.

2.7 Water requirements of *Aloe vera*

Aloe vera's survival depends on its ability to store and efficiently manage water. Naturally adapted to semi arid climates, it requires low to moderate water inputs, thriving with 300–500 mm of rainfall annually (Nejatzadeh, 2019). Its succulent leaves contain a mucilaginous gel that retains water for extended periods, enabling the plant to withstand drought conditions for weeks without irrigation. **Figure 10** illustrates *Aloe vera* plants being watered under controlled conditions, demonstrating the importance of moderate and well-managed irrigation. **Table 3** summarizes the environmental conditions related to water availability and other factors that support optimal growth.

Overwatering, however, poses a major threat. The plant's shallow, fibrous demand well-drained, sandy or loamy soils to prevent root rot (Tuttle , 2021). Controlled irrigation, allowing the soil to dry between watering cycles, supports optimal gel formation and root oxygenation. In commercial cultivation, drip irrigation systems are preferred to mimic natural desert moisture conditions. The plant's low evapotranspiration rate, combined with CAM photosynthesis, ensures water efficiency, making *Aloe vera* one of the most climate-resilient crops suitable for dry and degraded lands.

Figure 10

Aloe vera being watered



Note: This image illustrates *Aloe vera* plants being watered under controlled conditions, emphasizing the species' requirement for moderate hydration. It shows how *Aloe vera* benefits from occasional watering followed by dry periods, which mimics its natural arid habitat and prevents root rot. Adapted from (*The Shocking Truth about Aloe vera (and How to Remove the Latex)*, 2024)

Table 3**Environmental Requirements of *Aloe vera***

ENVIRONMENTAL FACTOR	OPTIMAL RANGE/CONDITION	ADAPTIVE FUNCTION
Daytime Temperature	20–30 °C	Optimal for photosynthesis
Nighttime Temperature	10–20 °C	Supports CAM gas exchange
Annual Rainfall	300–500 mm	Drought-tolerant with internal storage
Light Exposure	6–8 hours full sunlight	Promotes compact growth & aloin production
Soil Moisture	Low to moderate, well-drained	Prevents root rot
Relative Humidity	30–50 %	Ideal for minimizing fungal growth

Note: This table summarizes *Aloe vera*'s environmental needs and how each condition supports its physiological adaptations to arid ecosystems. Adapted from (Hamman, 2008).

2.8 Light and temperature regimens of *Aloe vera*

In its natural environment, *Aloe vera* grows in open, sun-exposed habitats, such as semideserts and dry savannas. It is a sun loving plant that requires 6–8 hours of sunlight per day to maintain compact rosette growth and maximize production of bioactive compounds like aloin and

acemannana (Horn, 2022). Under full sunlight, the leaves develop a healthy gray-green coloration, a sign of optimal photosynthetic activity and protected pigmentation. **Figure 11** shows *Aloe vera* receiving bright sunlight, illustrating the light conditions required for healthy growth and development.

However, in regions with very intense solar radiation, partial shade during the hottest hours can prevent leaf scorching. The plant's thick cuticle and waxy surface act as natural sun barriers, reflecting excessive light and preventing water loss through transpiration (Helena, 2025). These traits explain why *Aloe vera* is commonly cultivated in open fields or dry slopes rather than forest understories, where light intensity is low.

Figure 11

Sunlight for *Aloe vera*



Note: This image shows an *Aloe vera* plant placed indoors near a window where it receives bright, indirect sunlight. It demonstrates the plant's light preference, thriving in high light conditions but protected from intense, direct sun that could scorch its leaves. Adapted from (Hopson, 2025).

Aloe vera thrives in warm and semi arid climates, with an optimal growth temperature between 20-30 °C, where enzymatic and photosynthetic processes operate most efficiently. The plant tolerates high temperature up to 40 °C, but prolonged exposure to extreme heat can cause dehydration and cellular stress, reducing gel quality (*Aloe vera Care Guide*, 2019). Conversely, *Aloe vera* is sensitive to frost and suffers tissue damage below 5 °C, which limits its natural range to subtropical and tropical zones.

Unlike many temperate species, *Aloe vera* does not need a cold dormant period to trigger growth; it grows actively throughout the year in stable warm conditions. Its Crassulaceous Acid Metabolism (CAM) pathway is a key adaptation to hot environments: the plant opens its stomata at night to capture carbon dioxide, conserving water during the day. This makes it exceptionally tolerant of high temperatures and low humidity, ideal for regions such as northeastern Africa and the Arabian Peninsula (Old Farmer's Almanac, 2019).

3.0 Biology

3.1 Chromosome Complement

Aloe vera is a diploid plant species with a chromosome complement of $2n=14$, meaning that its somatic cells contain fourteen chromosomes arranged in seven homologous pairs (Cristiano et al., 2016). Cytological studies describe *Aloe vera* as having relatively large and easily observable chromosomes, which facilitates chromosomal analysis during mitosis (Haque & Ghosh, 2013b). Chromosomal stability is important for normal growth and vegetative propagation in *Aloe vera*. According to the National Library of Medicine, “The diploid chromosome number was found to diploid $2n = 14$ ” (Haque & Ghosh, 2013), indicating genetic stability even under propagation conditions. **Table 4** summarizes the key characteristics of the chromosome complement of *Aloe vera*, while **Figure 12** shows the karyotype and mitotic chromosomes, illustrating their structure and arrangement.

Chromosomal and genetic stability plays an important role in the successful propagation of *Aloe vera*. In a cytogenetic and molecular analysis, RAPD and ISSR markers were used. National Library of Medicine states that “to evaluate genetic stability of plantlets and validate the most reliable method for true-to-type propagation.” (Rathore et al., 2011) Demonstrating the importance of maintaining genetic fidelity during vegetative propagation. The relatively large chromosomes of *Aloe vera* make the species particularly suitable for cytogenetic studies, especially during mitotic stages such as metaphase. Although minor chromosomal variation may occur among cultivated varieties, the chromosome complement remains largely stable and plays

a key role in regulating growth, development, and the production of bioactive compounds characteristic of *Aloe vera*.

Table 4

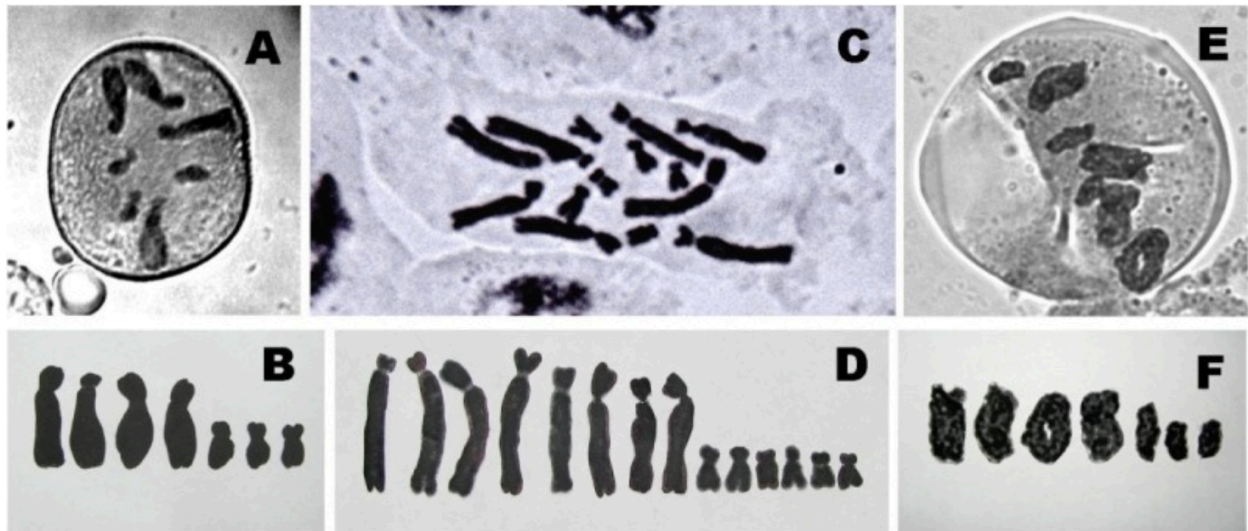
Chromosome complement of *Aloe vera*

CHARACTERISTICS	DESCRIPTION
Species	<i>Aloe vera</i>
Ploidy level	Diploid
Chromosome number	2n=14
Arrangement	Seven homologous pairs
Chromosome size	Relatively large and easily observable
Genetic stability	High, with minor variation among cultivars

Note: This table presents key information on the chromosome complement of *Aloe vera*, including its diploid chromosome number $2n = 14$ and chromosomal characteristics. The information is based on (Haque & Ghosh, 2013).

Figure 12

Karyotype of *Aloe vera* showing mitotic metaphase chromosomes ($2n = 14$).



Note: Microscopic images showing mitotic chromosomes and karyotype arrangements of *Aloe vera* illustrating the diploid chromosome complement ($2n = 14$). The relatively large chromosomes facilitate cytogenetic analysis. Scale bar = 10 μm . Adapted from (Haque & Ghosh, 2013b)

3.2 Life Cycle and Phenology

The life cycle and phenology of *Aloe vera* describe the sequence of developmental stages and the timing of growth and reproductive events in relation to environmental conditions. These processes are closely influenced by factors such as temperature, water availability, and light, which regulate both vegetative growth and flowering patterns in the species.

3.2.1 Life Cycle

The life cycle of *Aloe vera* begins with seed germination under favourable environmental conditions, such as warm temperatures and adequate moisture (Cristiano et al., 2016). Although sexual reproduction through seeds is possible, it is very uncommon in cultivated plants. After germination happens, seedlings grow slowly and develop into a basal rosette of thick succulent

leaves, which allows the plant to store water and survive in dry conditions. During this stage, most of the energy is invested in vegetative growth and root development.

As the plant matures, *Aloe vera* primarily reproduces through vegetative propagation by producing lateral shoots, commonly known as offsets or pups, at the base of the parent plant (Cristiano et al., 2016). These offsets develop their own root systems and enable clonal reproduction, which ensures genetic consistency. Flowering occurs only after the plant reaches maturity and represents the productive stage of the life cycle. After flowering and possible seed reproduction, the plant continues vegetative growth and can repeat this cycle over several years. This long-term growth pattern reflects the perennial nature of the species; as stated by the National Library of Medicine “the second year gives the maximum yield, and for about 4–5 years a good yield can be harvested” (Cristiano et al., 2016). Flowering occurs only after maturity, after which vegetative growth continues and the life cycle is repeated.

3.2.2 Phenology

Phenology in *Aloe vera* refers to the timing of growth and reproductive events in relation to environmental conditions. Vegetative growth is more active during warm periods with sufficient light and water availability, while growth slows during colder or drier conditions (Cousins et al., 2013). These seasonal growth patterns reflect the plant’s adaptation to environments with variable climatic conditions.

Flowering in *Aloe vera* is seasonal and generally occurs once per year, although the exact timing varies depending on temperature, photoperiod, and plant maturity (Cousins et al., 2013).

Environmental factors play a key role in the initiation of the reproductive phase and the

development of the inflorescence. Studies on *Aloe vera* growth and reproduction indicate that flowering and reproductive development are closely related to external climatic conditions rather than occurring continuously throughout the year. as noted in phenological studies, “large plants may not always produce more flowers than smaller ones owing to differences in local environmental conditions” (Cousins et al., 2013) This quote highlights the influence of climate and habitat on flowering patterns.

3.3 Anatomy and Growth Habits

The anatomy and growth habits of *Aloe vera* are closely related to its adaptation to arid and semi-arid environments. Its structural organization allows efficient water storage, reduced water loss, and sustained growth under conditions of limited water availability. These features are reflected in both the internal leaf anatomy and the overall growth pattern of the plant.

3.3.1 Anatomy

Aloe vera is a succulent plant characterized by a compact rosette of thick, fleshy leaves that arise from a short stem. The leaves are lance shaped, green to grey-green in color, and often possess small marginal teeth along the edges. This rosette arrangement allows the plant to efficiently capture sunlight while minimizing water loss. **Figure 13** shows the anatomical structure of an *Aloe vera* leaf, illustrating the different internal tissues such as the epidermis, mesophyll, and vascular bundles.

Anatomically, the leaves of *Aloe vera* are highly specialized for water storage. Each leaf consists of three main layers: an outer protective epidermis covered by a thick cuticle, a layer of chlorenchyma responsible for photosynthesis, and a central parenchymatous region that stores

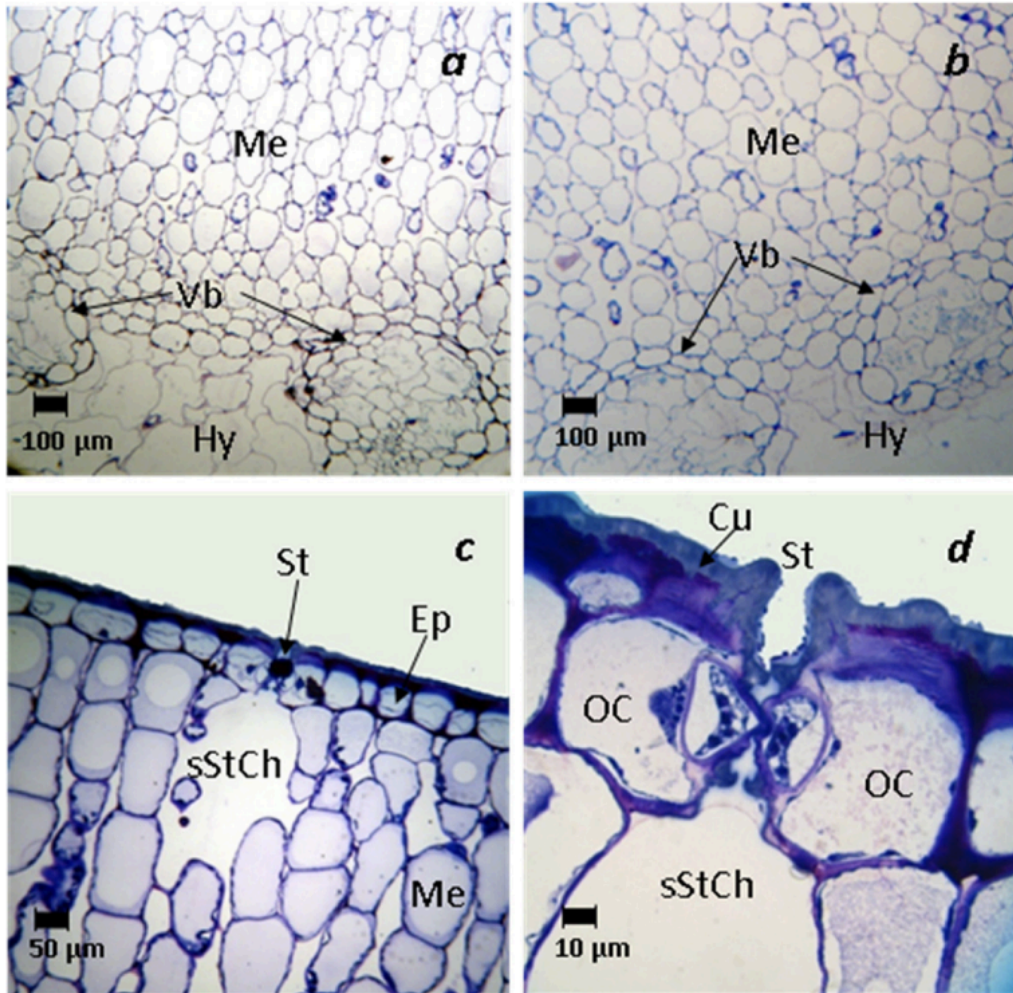
large quantities of water-rich gel. “The *Aloe vera* leaves are formed by a thick epidermis (skin) covered with cuticles surrounding the mesophyll, which can be differentiated into chlorenchyma cells and thinner walled cells forming the parenchyma” (Rathore et al., 2011) This internal gel issue is a defining anatomical feature of the species and plays a crucial role in maintaining cellular hydration during periods of drought.

The root system of *Aloe vera* is relatively shallow and fibrous, allowing rapid absorption of water following rainfall (Cousins et al., 2013). Although the roots do not penetrate deeply into the soil, they are effective in anchoring the plant and supporting nutrient uptake in arid and semi-arid environments. The stem is typically short and often not visible, as the leaves emerge directly from the base of the plant.

Overall, the anatomical structure of *Aloe vera* reflects its adaptation to water-limited environments. The combination of thick succulent leaves, protective epidermal layers, and an efficient root system enables the plant to survive prolonged dry conditions while maintaining growth and physiological activity.

Figure 13

Anatomical structure of an *Aloe vera* leaf.



Note: Light micrographs of *Aloe vera* leaf cross sections showing the epidermis (Ep), mesophyll (Me), vascular bundles (Vb), and stomatal structures (St). Adapted from (Silva et al., 2014)

3.3.2 Growth Habits

Aloe vera exhibits a slow growing, perennial growth habit typical of many succulent species (Cristiano et al., 2016). The plant grows as a basal rosette, with leaves emerging from a short, compact stem close to the soil surface. This growth form reduces exposure to wind and excessive sunlight, helping to limit water loss in arid and semi-arid environments.

Vegetative growth is the dominant growth strategy in *Aloe vera*. The plant commonly produces lateral shoots or offsets, also known as pups, which develop at the base of the parent plant. These offsets allow the species to spread locally and form clumps over time, contributing to its persistence and ease of propagation. This clonal growth habit is particularly advantageous in environments where seed germination is limited.

Growth in *Aloe vera* is generally continuous under favorable conditions but slows significantly during periods of low temperature or water stress. The shallow root system supports this growth habit by enabling rapid uptake of water following rainfall, while stored water in the leaves sustains the plant during dry periods. As noted in an article of the National Library of Medicine “The second year gives the maximum yield, and for about 4–5 years a good yield can be harvested.”(Cristiano et al., 2016). Overall, the growth habits of *Aloe vera* reflect strong adaptation to environments with irregular water availability.

3.4 Reproductive Biology

The reproductive biology of *Aloe vera* includes both sexual and asexual mechanisms that contribute to its survival and propagation. While the species is capable of producing seeds through flowering and pollination, vegetative reproduction through offsets is the dominant and most efficient method, particularly in cultivated environments.

3.4.1 Sexual Reproduction

Sexual reproduction in *Aloe vera* occurs through the production of flowers, pollination, and subsequent seed formation. Mature plants produce a tall, erect inflorescence that emerges from the center of the rosette. The inflorescence bears numerous tubular flowers, typically yellow to

orange in color, which are arranged along a flowering stalk. These flowers are structurally adapted to attract pollinators.

The flowers of *Aloe vera* are bisexual, containing both male (stamens) and female (pistil) reproductive organs. Pollen is released from the anthers and must be transferred to the stigma for fertilization to occur. Pollination is commonly carried out by insects and birds, which are attracted by the bright coloration and nectar produced by the flowers (Cristiano et al., 2016). “*A. vera* is generally self-incompatible, seeds are only fertile if they derive from cross pollination” (Cristiano et al., 2016) Following successful pollination and fertilization, seeds develop within the fruit.

Although *Aloe vera* is capable of producing seeds, seed reproduction is relatively uncommon in cultivated plants. This is due to factors such as limited pollinator activity, environmental conditions, and the plant’s reliance on vegetative reproduction. As a result, sexual reproduction plays a secondary role in the life cycle of *Aloe vera* compared to asexual propagation.

3.4.2 Asexual Reproduction

Asexual reproduction is the primary and most common mode of reproduction in *Aloe vera*. This process occurs through vegetative propagation, mainly by the production of lateral shoots known as offsets or pups. As noted in studies “Traditionally, *Aloe vera* is propagated using suckers (lateral shoots) and rhizome cuttings as planting materials.” (Cristiano et al., 2016). These offsets develop at the base of the parent plant and remain attached until they are sufficiently mature to survive independently.

As the offsets grow, they form their own root system while still benefiting from the resources of the parent plant. Once established, they can be naturally separated or manually removed and replanted, allowing rapid and efficient propagation. This method ensures that new plants are genetically identical to the parent, preserving desirable traits such as growth form, gel quality, and environmental tolerance (Cristiano et al., 2016).

Asexual reproduction provides several advantages for *Aloe vera*, particularly in cultivated and arid environments. It allows reliable reproduction without the need for pollination or seed germination, which can be limited by environmental conditions. As a result, vegetative propagation plays a dominant role in the persistence, spread, and agricultural production of *Aloe vera*, making it the preferred method for commercial cultivation.

3.5 Ecophysiology

Ecophysiology in *Aloe vera* refers to how the plant's physiological processes allow it to survive and function under specific conditions, particularly arid and semi-arid climates. The species exhibits several adaptations that enable efficient water use, tolerance to high temperatures, and survival during prolonged periods of drought (Cristiano et al., 2016). **Table 5** summarizes the main ecophysiological adaptations of *Aloe vera* and their functional advantages, while **Figure 14** illustrates the CAM photosynthesis pathway that supports water-efficient metabolism.

One of the most important ecophysiological adaptations of *Aloe vera* is Crassulacean Acid Metabolism (CAM) photosynthesis. Through this pathway, stomata open primarily at night to absorb carbon dioxide, reducing water loss through transpiration during the hot daytime hours. As described in studies on CAM plants, "Crassulacean acid metabolism (CAM) is an

ecophysiological adaptation of C3 photosynthesis that shifts part or all of primary atmospheric CO₂ fixation to the dark period, thereby affording economical water use by reducing transpirational water losses.” (Rathore et al., 2011). This adaptation significantly increases water use efficiency and allows the plants to maintain photosynthetic activity under dry conditions.

Water storage is another key ecophysiological feature (Cristiano et al.2016). The thick, succulent leaves store large quantities of water in their gel filled parenchyma, which can be mobilized during periods of limited water availability. In addition, a thick cuticle and regulated stomatal activity further reduce water loss. The shallow root system complements these adaptations by enabling rapid water uptake following rainfall.

Together, these ecophysiological traits allow *Aloe vera* to persist in environments characterized by irregular precipitation, high solar radiation, and elevated temperatures, making it well adapted to drought-prone ecosystems and cultivated systems with limited water input.

Table 5

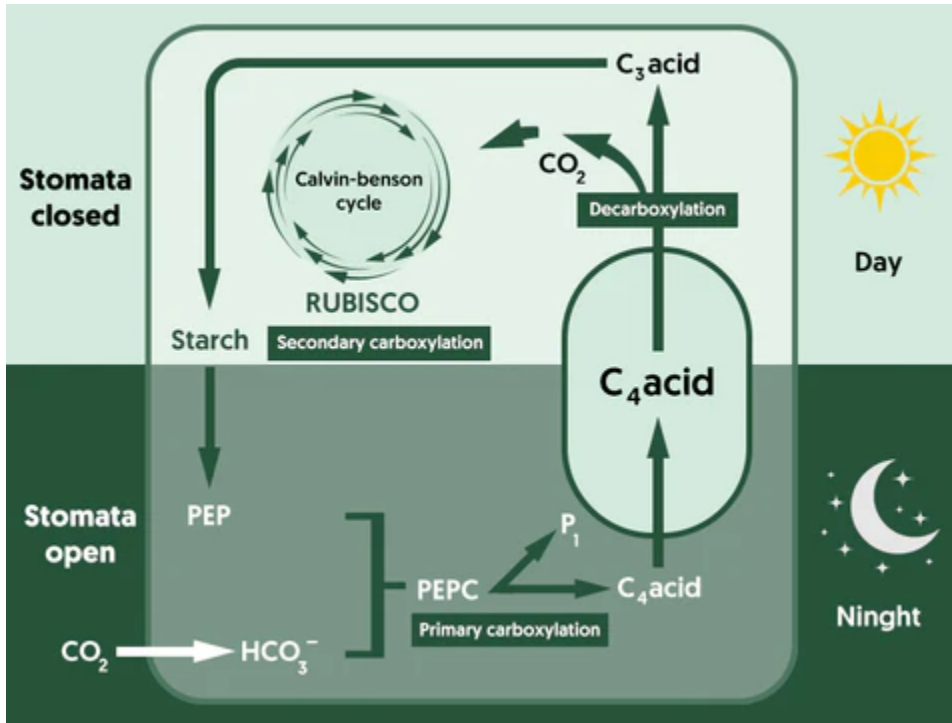
Ecophysiological adaptations of *Aloe vera*

ENVIRONMENTAL FACTOR	ECOPHYSIOLOGICAL ADAPTATION	FUNCTIONAL ADVANTAGE
Water availability	Ecophysiological adaptations of <i>Aloe vera</i>	Long-term water storage during drought
Temperature	CAM photosynthesis	Reduced water loss in hot conditions
Light intensity	Night-time CO ₂ uptake	Protection from daytime heat stress
Drought	Thick cuticle and stomatal control	Minimizes transpiration
Soil moisture	Shallow, fibrous root system	Rapid water uptake after rainfall

Note: This table summarizes the major ecophysiological adaptations of *Aloe vera* that support survival and growth in arid and semi-arid environments. This table is adjusted from (Cristiano et al., 2016)

Image 14

Crassulacean Acid Metabolism (CAM) photosynthesis pathway in *Aloe vera*.



Note: Crassulacean Acid Metabolism (CAM) photosynthesis pathway in *Aloe vera*, showing nocturnal CO₂ uptake and daytime carbon fixation that reduce water loss under arid conditions. Image from (Haque & Ghosh, 2013)

4.0 Propagation and management

4.1 Natural Regeneration

Natural regeneration in *Aloe vera* primarily occurs through vegetative propagation rather than sexual seed reproduction. In its native arid and semi arid environments, *Aloe vera* produces lateral shoots, commonly called “pups” or basal offsets, which develop directly from the main clump of the plant (see **figure 15**) (Arizaga & Ezcurra, 2002). These offsets are essentially miniature clones of the parent plant and contain identical genetic material, which ensures that desirable traits such as gel content and drought tolerance, are maintained across generations (Arizaga & Ezcurra, 2002).

Vegetative propagation is considered the dominant form of natural regeneration in *Aloe vera* because its seeds are often produced at low frequency and have limited viability under natural conditions (Amoo et al., 2022). Flowering in cultivated and wild populations may occur only after plants reach maturity, typically after 2-3 years of vegetative growth (Martínez-Sánchez et al., 2020). Even when seeds are produced, their germination rate is highly dependent on specific environmental conditions like soil moisture, temperature, and light exposure (Abihudi et al., 2020).

This reliance on vegetative regeneration is advantageous in the xerophytic (very dry) ecosystems where *Aloe vera* is indigenous. Suited to environments with irregular rainfall and poor soils, the species has evolved to efficiently conserve water and nutrients within its fleshy leaves. Isolated seedlings that emerge from seed germination often struggle to establish stable root systems in

such harsh conditions, further reinforcing the effectiveness of clonal reproduction for population maintenance (Arizaga & Ezcurra, 2002).

During natural regeneration, basal offsets form at the base of the rosette and remain connected to the mother plant through a central corm like stem structure (Arizaga & Ezcurra, 2002). After developing a sufficient number of roots and leaves, these offsets can become independent individuals if separated manually or naturally due to soil disturbances. In managed agricultural production, growers intentionally separate these offsets to propagate new plants, thus utilizing the natural regenerative process for cultivation purposes (Arizaga & Ezcurra, 2002).

4.2 Nursery Propagation

Nursery propagation is an important stage in the cultivation of *Aloe vera* because it allows young plants to develop under controlled environmental conditions before being transplanted into the field. This stage ensures higher survival rates, uniform plant growth, and improved root establishment (Cristiano et al., 2016). **Table 6** summarizes the recommended nursery conditions for *Aloe vera* propagation, including soil type, temperature, light, and irrigation requirements.

In the nursery systems, propagation is typically carried out using either seeds or vegetative offsets obtained from mature plants. The seedlings or offsets are initially grown in small containers or nursery beds containing well drained sandy or loamy soil. Proper drainage is essential because *Aloe vera* is highly susceptible to root rot when exposed to excessive soil moisture (Cristiano et al., 2016).

Environmental conditions within the nursery must be carefully managed to promote healthy growth. Moderate irrigation, typically involving watering once or twice per week and allowing

the soil to dry between watering cycles, adequate sunlight, and suitable temperature ranges are required for optimal development. *Aloe vera* thrives in warm climates, and nursery temperatures between approximately 20°C and 30°C are considered favorable for root development and early vegetative growth (Kashyap et al., 2025).

Nursery propagation also helps protect young plants from environmental stress such as extreme heat, heavy rainfall, and pest infestations. During this stage, growers can monitor plant health closely and remove weak or diseased individuals before transplantation. Once the plants have developed a stable root systems and several mature leaves, they are ready to be transferred to their final planting location. Overall, nursery propagation improves plant establishment and ensures the production of vigorous, uniform plants suitable for commercial cultivation.

Table 6**Recommended nursery conditions for propagation of *Aloe vera***

FACTOR	RECOMMENDED CONDITION	IMPORTANCE
Soil type	Sandy or sandy-loam soil	Ensures good drainage and prevents root rot
Temperature	20-30°C	Promotes root growth and seedling development
Light	Full sunlight or partial shade	Supports photosynthesis and healthy growth
Irrigation	Light irrigation once or twice per week, allowing soil to dry between watering	Prevents waterlogging and reduces risk of root rot
Containers	Nursery trays or small pots	Allows controlled early development
Spacing	Adequate spacing between plants	Reduces disease transmission

Note: This table shows proper nursery management improves plant survival, root establishment, and uniformity before transplantation into the field. Adapted from (Kashyap et al., 2025).

4.2.1 Propagation from seed

Propagation from seed represents the sexual reproductive method in *Aloe vera*. Although this method occurs naturally after flowering and pollination, it is not commonly used in commercial cultivation because it produces genetically variable offspring and requires longer growth periods compared with vegetative propagation (Kashyap et al., 2025). **Table 7** summarizes the main characteristics of seed propagation in *Aloe vera*, including reproductive type, germination conditions, and agricultural use.

In mature plants, flowering occurs through the development of a tall inflorescence bearing tubular yellow or orange flowers. After successful pollination, these flowers produce capsule type fruits containing numerous small black seeds (Admin et al., 2024). Once the capsules mature and dry, the seeds can be collected and used for propagation.

For successful germination, *Aloe vera* seeds are typically sown in well drained, light texture substrates such as sandy soil or a mixture of sand and organic matter. The seeds are usually placed on the soil surface and lightly covered to allow sufficient light penetration, which promotes germination. Optimal germination conditions generally include temperature between 20°C and 25°C and moderate soil moisture (Kashyap et al., 2025).

Seed germination usually occurs within two or four weeks under favorable environmental conditions. However, several limitations reduce the use of this propagation method. Seedlings often show significant genetic variation, which may affect plant characteristics such as growth rate, leaf size, and gel composition. Because many medicinal and commercial applications of *Aloe vera* depend on consistent phytochemical properties, uniformity is highly desirable in cultivated plants (Kashyap et al., 2025).

Another limitation is the slower establishment rate of seedlings compared with vegetative offsets. Plants propagated from seed required longer periods to reach maturity and produce harvestable leaves. As a result, seed propagation is mainly used for scientific research, breeding programs, or genetic studies rather than for large scale agricultural production.

Despite these limitations, seed propagation remains important for maintaining genetic diversity and for developing improved varieties through plant breeding.

Table 7

Characteristics of seed propagation in *Aloe vera*

ASPECTS	DESCRIPTION
Reproductive type	Sexual reproduction
Plant structures involved	Flowers, capsules, and seeds
Germination time	Approximately 2-4 weeks
Optimal temperature	Around 20-25°C
Genetic outcome	High genetic variation
Agricultural use	Limited; mainly research and breeding

Note: Seed propagation allows genetic diversity but is less commonly used in commercial cultivation due to variability in plant traits and slower plant development (Kashyap et al., 2025).

4.2.2 Vegetative propagation

Vegetative propagation is the most common and efficient method used for the cultivation of *Aloe vera*. Unlike seed propagation, which produces genetically variable offspring, vegetative propagation generates new plants that are genetically identical to the parental plant. This ensures uniform growth characteristics and consistent phytochemical composition, which is particularly important for medicinal and commercial uses of *Aloe vera* (Kashyap et al., 2025).

In *Aloe vera*, vegetative propagation occurs through the formation of basal offsets, commonly referred to as “pups” or suckers. **Table 8** summarizes the main advantages of vegetative propagation in *Aloe vera*, while **Figure 15** shows basal offsets (“pups”) used for this method. These offshoots develop from axillary buds located at the base of mature plants and gradually form their own root systems while still attached to the mother plant (Arizaga & Ezcurra, 2002). As the offsets grow, they produce leaves arranged in a rosette similar to the parent plant, allowing them to function as independent individuals once separated.

For propagation purposes, growers typically select healthy offsets that have reached a height of approximately 8-15 cm and have developed several leaves and a small root system. The offsets are carefully removed from the base of the mother plant using clean tools to prevent damage or infection. After separation, the offsets are usually left to dry for one or two days so that the cut surface can heal and reduce the risk of fungal infection when planted (Kashyap et al., 2025).

The separated offsets are then planted in well-drained soil, commonly consisting of sandy or sandy loam substrates that allow excess water to drain quickly. Moderate watering is recommended during the initial establishment period, since excessive moisture may lead to root

rot. Under suitable environmental conditions, the young plants establish roots and begin active vegetative growth within a few weeks.

Vegetative propagation offers several advantages over seed propagation. The method is faster, more reliable, and ensures uniformity in plant traits such as leaf size, gel yield, and chemical composition. For these reasons, most commercial *Aloe vera* plantations rely almost exclusively on vegetative propagation through offsets (Kashyap et al., 2025).

Table 8

Advantages of vegetative propagation in *Aloe vera*

ADVANTAGE	EXPLANATION
Genetic uniformity	New plants are clones of the parent plant
Faster establishment	Offsets grow faster than seedlings
Consistent medicinal quality	Maintains stable phytochemical composition
High survival rate	Rooted offsets establish easily in suitable soil
Preferred for cultivation	Widely used in commercial plantations

Note: Vegetative propagation through basal offsets is the primary method used in the cultivation of *Aloe vera* due to its reliability and ability to maintain desirable plant traits (Kashyap et al., 2025).

Figure 15

***Aloe vera* basal offsets**



Note: Basal offsets (“pups”) of *Aloe vera* showing developed roots used for vegetative propagation. Image from (Foster, 2017).

4.3 Planting

Planting is a critical stage in the cultivation of *Aloe vera*, as proper establishment of the plant in the soil directly influences its growth, survival rate, and productivity. After successful propagation in the nursery or through vegetative offsets, young plants are transplanted into their final growing location where they can develop fully under suitable environmental conditions (Kashyap et al., 2025). **Table 9** summarizes the recommended planting conditions for *Aloe vera*, including soil type, pH, spacing, climate, and irrigation requirements.

Aloe vera grows best in well drained soils, particularly sandy or sandy loam soil that allows excess water to drain easily. This characteristic is essential because the species is highly sensitive to waterlogging, which can cause root rot and other fungal diseases. The ideal soil pH for *Aloe vera* cultivation typically ranges from slightly acidic to neutral, approximately between pH 6.0 and 7.5 (Kashyap et al., 2025).

Spacing between plants is another important factor during planting. Adequate spacing allows each plant to receive sufficient sunlight, nutrients, and air circulation, while also providing room for the development of basal offsets. In commercial cultivation, plants are usually spaced between 45 and 60cm apart to support healthy growth and prevent overcrowding (Kashyap et al., 2025).

Before planting, the soil is often prepared by loosening it and incorporating organic matter such as compost or manure to improve soil fertility and structure. The propagated offsets or seedlings are then carefully placed into shallow holes, ensuring that the roots are fully covered with soil while the base of the plant remains above the surface to prevent moisture accumulation around the stem.

After planting, light irrigation may be applied to help the roots establish in the soil. However, excessive watering should be avoided because *Aloe vera* is a drought tolerant succulent adapted to arid and semi arid climates. Once established, the plants require minimal watering and maintenance compared with many other agricultural crops.

Proper planting practices are therefore essential to ensure successful establishment and long term productivity of *Aloe vera* plants in both small scale and commercial cultivation systems.

Table 9

Recommended planting conditions for *Aloe vera*

FACTOR	RECOMMENDED CONDITION
Soil type	Sandy or sandy loam, well drained
Soil pH	6.0-7.5
Plant spacing	45-60 cm between plants
Climate	Warm, dry environments
Irrigation	Light irrigation during establishment

Note: Proper soil drainage, spacing, and moderate irrigation are essential for the successful establishment of *Aloe vera* plants after transplantation (Kashyap et al., 2025).

4.4 Tending

Tending refers to the routine care and management practices required to ensure the healthy growth and development of *Aloe vera* plants after they have been established in the field. Proper tending practices help maintain plant health, improve leaf production, and reduce the risk of pests and diseases. **Table 10** shows the main tending practices in the cultivation of *Aloe vera* and their purposes.

One of the most important aspects of tending *Aloe vera* is irrigation management. As a succulent plant adapted to arid and semi arid environments, *Aloe vera* has the ability to store water in its

thick fleshy leaves. Because of this adaptation, the plant requires relatively low amounts of water compared to many other crops. Overwatering can be harmful and may lead to root rot or fungal infections. Therefore, irrigation should be applied approximately once every 7–10 days, allowing the soil to dry completely between watering cycles (Kashyap et al., 2025).

Weed control is another important component of tending. Weeds compete with *Aloe vera* plants for nutrients, water, and sunlight, which may reduce plant growth and productivity. Regular removal of weeds helps maintain adequate nutrient availability and allows the plants to grow without competition (Kashyap et al., 2025).

Soil management also plays an important role in proper plant care. Periodic loosening of the soil around the plants improves soil aeration and water infiltration, promoting healthy root development. In some cases, organic fertilizers such as compost or well decomposed manure may be applied to improve soil fertility and support plant growth.

Overall, proper tending practices ensure that *Aloe vera* plants remain healthy, productive, and capable of producing high quality leaves for medicinal, cosmetic, and commercial purposes.

Table 10

Main tending practices in the cultivation of *Aloe vera*

PRACTICE	PURPOSE
Irrigation	Provides water while preventing excess moisture
Weed control	Reduces competition for nutrients and sunlight
Soil loosening	Improves aeration and root development
Fertilization	Supplies nutrients for plant growth
Plant monitoring	Detects pests, diseases, or growth problems

Note: Proper tending practices such as controlled irrigation, weed management, and soil maintenance contribute to the healthy growth and productivity of *Aloe vera* plants (Kashyap et al., 2025).

4.5 Fruiting

Fruiting in *Aloe vera* occurs as a result of sexual reproduction following the flowering stage. Mature plants produce a tall flowering stalk known as an inflorescence, which bears numerous tubular flowers typically yellow or orange in color. **Figure 16** shows the flowering inflorescence of *Aloe vera*, illustrating the tubular flowers that later develop into fruits after pollination. These flowers are arranged in clusters along the flowering spike and are usually pollinated by insects or birds (Admin et al., 2024).

After successful pollination and fertilization, the flowers develop into small capsule type fruits. Each capsule contains several seeds that can potentially be used for propagation. However, fruit production is not considered economically important in the cultivation of *Aloe vera*, since the plant is primarily grown for its fleshy leaves and the medicinal gel they contain (Martínez-Sánchez et al., 2020).

In addition, fruit and seed production in cultivated *Aloe vera* plants is relatively uncommon because many plants are propagated vegetatively through basal offsets rather than through sexual reproduction. As a result, flowering and fruiting are mainly observed in mature plants growing under favorable environmental conditions such as adequate sunlight and proper temperature.

Although fruiting plays a minor role in commercial production, it remains biologically significant because it allows for genetic variation and the potential development of new plant varieties through seed propagation.

Figure 16

Flowering inflorescence of *Aloe vera*



Note: Aloe vera fruit capsules developing on the flowering stalk, containing seeds used for reproduction. (Craven, 2022)

4.6 Pest and disease control

Although *Aloe vera* is generally considered a hardy and resilient plant, it can still be affected by several pests and diseases that may reduce plant health and productivity. Proper pest and disease management is therefore important in maintaining healthy plants and ensuring successful

cultivation. **Table 11** summarizes the most common pests and diseases affecting *Aloe vera*, along with their causes, symptoms, and control methods.

One of the most common problems affecting *Aloe vera* is root rot, which is usually caused by excessive soil moisture and poor drainage. This condition allows fungi to develop in the soil and attack the plant's root system, causing the roots to decay and the plant to weaken or die.

Preventing waterlogging and maintaining well drained soil are essential measures to reduce the risk of this disease (Kashyap et al., 2025).

Certain insect pests can also affect *Aloe vera*. Mealybugs and aphids are among the most frequently observed pests. These insects feed on plant sap, which may lead to weakened growth, yellowing leaves, and reduced plant vigor. Regular inspection of plants can help detect infestations early and prevent their spread.

In addition to insect pests, fungal infections may occasionally appear on the leaves in the form of spots or discoloration. These diseases are often associated with excessive humidity, poor air circulation, or improper irrigation practices.

Effective pest and disease control in *Aloe vera* cultivation generally relies on preventive measures. These include maintaining proper irrigation practices, ensuring good soil drainage, removing infected plant material, and regularly monitoring plants for signs of pests or disease. In some cases, biological or mild chemical treatments may be applied when infestations become severe.

Through proper management and preventive care, most pest and disease problems in *Aloe vera* can be minimized, allowing plants to grow healthy and productive.

Table 11**Common pests and diseases affecting *Aloe vera***

PEST/DISEASE	CAUSE	SYMPTOMS	CONTROL METHOD
Root rot	Fungal infection due to excess moisture	Soft or decaying roots, plants wilting	Improve soil drainage and reduce watering
Mealybugs	Sap-sucking insects	White cotton-like clusters on leaves	Remove manually or apply insecticidal soap
Aphids	Sap-feeding insects	Leaf yellowing and weakened growth	Biological control or mild insecticides
Leaf spot	Fungal infection	Dark spots or discoloration on leaves	Remove infected leaves and improve airflow

Note: Proper irrigation management, sanitation, and plant monitoring are essential practices for preventing pest and disease problems in *Aloe vera* cultivation (Kashyap et al., 2025).

5.0 Importance, markets, and uses

5.1 Global and Regional Market Overview

Aloe vera has become an increasingly important commercial crop due to its wide range of applications in the cosmetic, pharmaceutical, and food industries (Eshun & He, 2004). In recent decades, global demand for *Aloe vera* has increased significantly, largely driven by consumer preference for natural, plant-based, and health-related products, as well as its expanding use across multiple industries (*Aloe vera Extract Market Size, Share, Growth & Trends [2030]*, 2026). As a result, *Aloe vera* is now cultivated and traded on an international scale, making it a valuable commodity in the global agricultural market (Eshun & He, 2004).

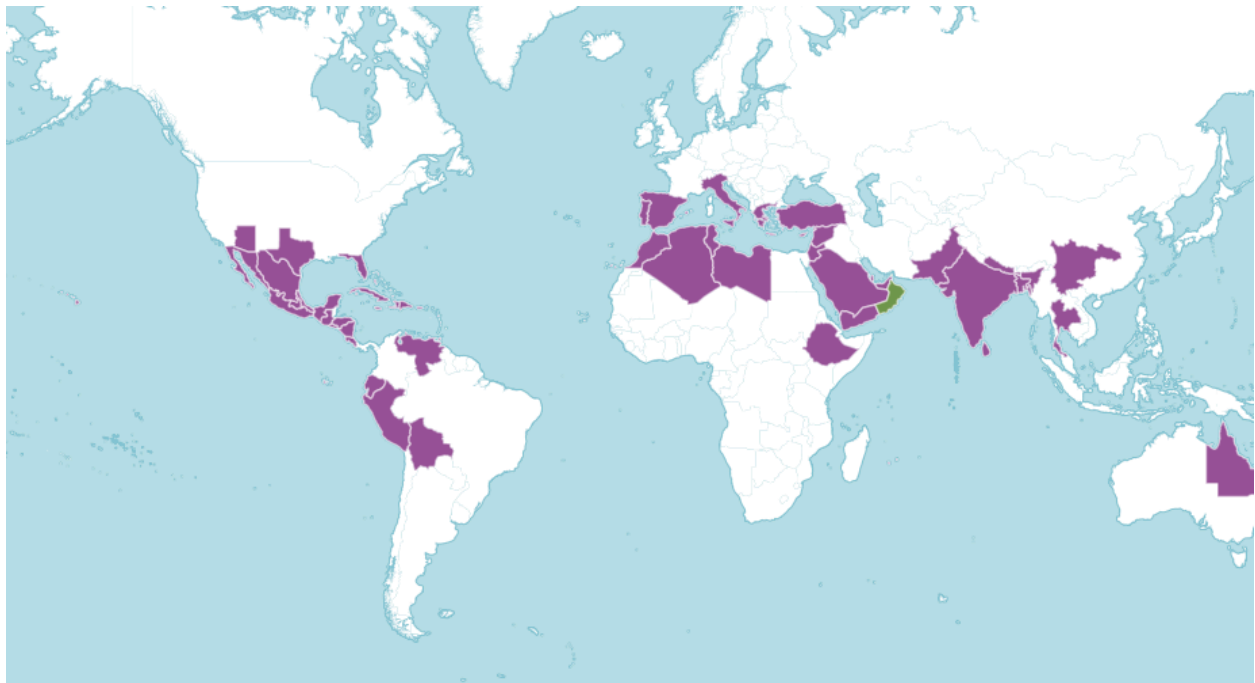
Regionally, *Aloe vera* is primarily grown in tropical and semi-arid areas where environmental conditions such as warm temperatures, well-drained soils, and low rainfall favor its growth (Kumar et al., 2017). *Aloe vera* is widely produced in several regions around the world, with countries in Asia, Latin America, and Africa contributing significantly to its cultivation and the supply of both raw leaves and processed products such as gel and extracts (Eshun & He, 2004). The global distribution of *Aloe vera* cultivation is illustrated in **Figure 17**. In many of these regions, *Aloe vera* cultivation has expanded due to its relatively low maintenance requirements and its ability to grow in conditions where other crops may not thrive (Kumar et al., 2017).

In addition to international trade, *Aloe vera* is also sold within domestic markets, particularly in countries where it is widely cultivated. Locally, it is used in fresh form or processed into juices, cosmetics, and medicinal products (Eshun & He, 2004). However, a significant portion of *Aloe*

vera production is directed toward export markets, where it is used and international trade highlights the plant's growing economic importance both regionally and globally.

Figure 17

Distribution of *Aloe vera*



Note: The figure illustrates the global distribution of *Aloe vera*, highlighting its presence in tropical and semi-arid regions where environmental conditions support its growth. Adapted from (*Aloe vera* - *Aloe vera* | *Plants* | *Kew*, n.d.)

5.1.1 Major Producing Countries

Aloe vera is cultivated in several regions of the world, particularly in countries with warm climates and semi-arid environmental conditions. Major producers include India, China, Mexico, the Dominican Republic, and parts of East Africa, where the plant is grown both for domestic use and international export (Mensah et al., 2025). Major producing countries and their importance are summarized in **Table 12**. These countries have become key contributors to the

global *Aloe vera* industry due to favorable growing conditions and increasing demand for Aloe-based products. In many of these regions, *Aloe vera* is cultivated on both small and large scales, supporting agricultural economies and supplying raw materials for processing industries.

Table 12

Major *Aloe vera* Producing Countries

COUNTRY	IMPORTANCE IN ALOE VERA PRODUCTION
India	One of the largest producers; large-scale cultivation and export of Aloe products
China	Major producer and exporter; strong presence in the cosmetic and pharmaceutical industries
Mexico	Significant producer, supplies both domestic and international markets
Dominican Republic	Important exporter of <i>Aloe vera</i> products, particularly to North America
Kenya and Tanzania	Key producers in East Africa; Aloe cultivation supports local economies and export markets

Note: This table summarizes major *Aloe vera* producing countries, adapted from (Mensah et al., 2025).

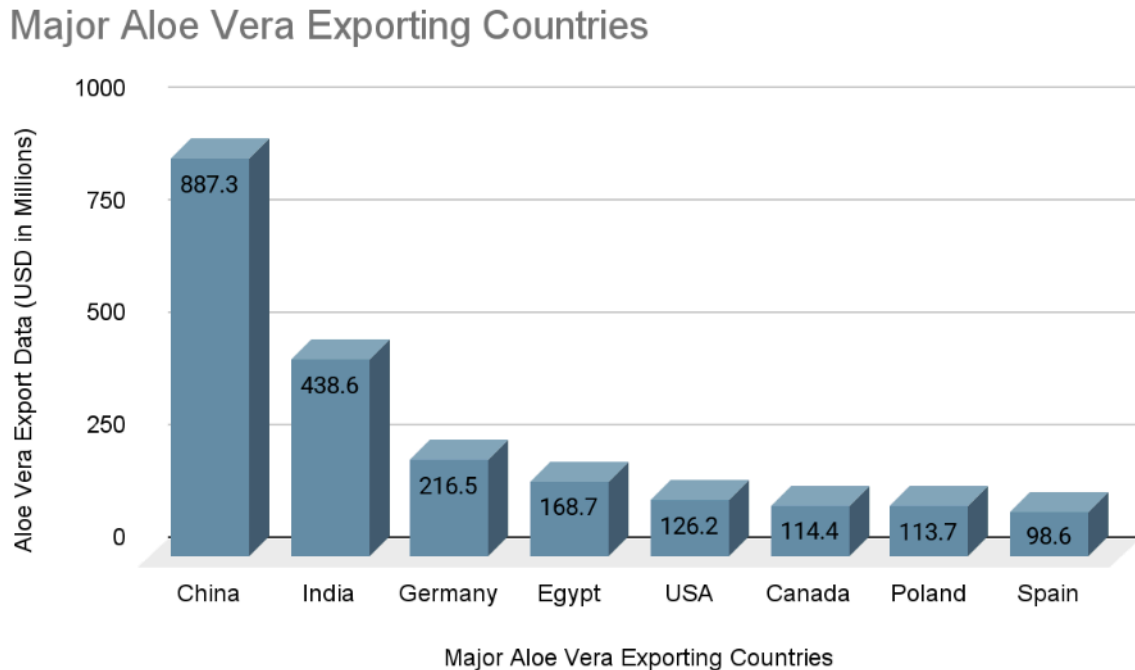
5.2 Production and Economic Value

The production and economic value of *Aloe vera* have increased significantly in recent years due to its expanding use across multiple industries. The global market for *Aloe vera* products is valued in the billions of dollars, reflecting its importance as both an agricultural crop and a commercial commodity (*Aloe vera Extract Market Size, Share, Growth & Trends [2030]*, 2026).

The economic importance of *Aloe vera* exports is illustrated in **Figure 18**. Large quantities of Aloe leaves are cultivated annually and processed into products such as gel, extracts, and powders, which are then distributed to international markets. This high level of production supports industries including cosmetic, pharmaceutical, and food manufacturing, further increasing the plant's economic significance (Eshun & He, 2004).

Figure 18

Data of Countries Exploring *Aloe Vera*



Note: This figure highlights the leading exporting countries and their contribution to the global *Aloe vera* market (Fortune Business Insights, n.d.).

5.3 Food Products Derived from *Aloe vera*

Aloe vera is not only valued for its medicinal and cosmetic uses but also for its applications in the food industry. The inner gel of the plant is processed into a variety of consumable products that are marketed for their nutrition and health-related properties (Eshun & He, 2004). Due to its high water content and the presence of bioactive compounds, *Aloe vera* is often considered a functional food ingredient that may support digestion and overall well-being (Surjushe et al., 2008).

5.3.1 Fresh Gel

The fresh gel extracted from the inner leaf of *Aloe vera* can be consumed directly or incorporated into foods such as smoothies and salads (Eshun & He, 2004). It is valued for its high water content and mild taste, making it suitable for inclusion in health-focused diets. However, proper preparation is necessary to remove compounds such as aloin, which can be harmful if consumed in large quantities (Surjushe et al., 2008).

5.3.2 Juice and Beverages

Aloe vera is widely used in the production of juices and beverages, often combined with fruit flavors to improve taste and consumer appeal (Eshun & He, 2004). These products are popular in both domestic and international markets and are commonly marketed as health drinks due to their perceived nutritional and functional benefits. The increasing demand for natural and plant-based beverages has contributed to the expansion of Aloe-based drinks within the global food industry (Fortune Business Insights, n.d.).

5.4 Cosmetic and Medicinal Products

Aloe vera is widely used in both the cosmetic and pharmaceutical industries due to its soothing, moisturizing, and healing properties (Eshun & He, 2004). The plant contains a variety of bioactive compounds, including vitamins, enzymes, amino acids, and polysaccharides, (Surjushe et al., 2008). These properties make *Aloe vera* a valuable ingredient in commercial products designed to protect the skin, promote healing, and support overall health. As demand for natural and plant-based products continues to grow, the use of *Aloe vera* in these industries has expanded significantly (Fortune Business Insights, n.d.).

5.4.1 Cosmetic Products

In the cosmetic industry, *Aloe vera* is widely incorporated into products such as creams, lotions, shampoos, conditioners, and facial treatments. Its high water content and ability to retain moisture make it an effective natural moisturizer, helping to hydrate the skin and maintain elasticity (Surjushe et al., 2008). Additionally, its anti-inflammatory and antimicrobial properties allow it to soothe irritated or damaged skin, making it particularly useful in products designed for sensitive skin and after-sun care (Eshun & He, 2004).

5.4.2 Medical and Pharmaceutical Products

Aloe vera is widely used in medical and pharmaceutical applications, particularly for the treatment of burns, wounds, and minor skin conditions (Eshun & He, 2004). The gel of the plant has been shown to promote wound healing by stimulating cell regeneration and reducing inflammation, making it a common ingredient in topical treatments. Its antimicrobial properties also help prevent infection, further enhancing its effectiveness in skin-related therapies (Surjushe et al., 2008). The various applications of *Aloe vera* in food, cosmetic, and medicinal products are illustrated in **Figure 19**.

In addition to topical applications, *Aloe vera* is used in certain digestive health products due to its potential therapeutic effects on the gastrointestinal system. However, its internal use must be carefully controlled, as compounds such as aloin may cause adverse effects if consumed in excessive amounts (Surjushe et al., 2008). These medicinal properties have contributed to the continued use of *Aloe vera* in both traditional medicine and modern pharmaceutical products.

Figure 19

Applications of *Aloe vera* in food, cosmetic, and medicinal products



Note: This figure illustrates the various applications of *Aloe vera*, including its use in food products, cosmetics formulations, and medicinal treatments. Image from (Adlakha et al., 2021)

5.5 Value to Local Economies

The cultivation of *Aloe vera* provides significant economic benefits at the local level, particularly in regions where environmental conditions limit the production of other crops. Due to its low water requirements and ability to grow in semi-arid environments, *Aloe vera* offers a reliable source of income for small-scale farmers (Surjushe et al., 2008). Its relatively low maintenance costs and high market demand make it an attractive crop for agricultural communities.

In many producing regions, *Aloe vera* contributes to job creation not only in farming but also in processing, packaging, and distribution. Local industries often develop around the production of

Aloe-based products such as gels, juices, and cosmetics, which can be sold both domestically and internationally (Fortune Business Insights, n.d.). This helps stimulate economic growth and supports the development of small and medium-sized enterprises.

Furthermore, the increasing global demand for natural and plant-based products has enhanced the economic value of *Aloe vera*, creating new market opportunities for local producers. As a result, the cultivation and commercialization of *Aloe vera* play an important role in supporting rural livelihoods and promoting sustainable agricultural practices in various regions around the world.

References

- Abihudi, S. A., Venkataramana, P. B., de Boer, H. J., & Treydte, A. C. (2020). Species-specific responses of “Critically Endangered” and “Least Concern” Aloe seed germination to environmental conditions in Tanzania. *Global Ecology and Conservation*, 24, e01241. <https://doi.org/10.1016/j.gecco.2020.e01241>
- Adlakha, K., Koul, B., & Kumar, A. (2021). Value-added products of Aloe species: Panacea to several maladies. *South African Journal of Botany*. <https://doi.org/10.1016/j.sajb.2020.12.025>
- Admin, A., Egli, U., Griebeler, A., Stefanaki, A., Cronier, M., & Isager Ahl, L. I. (2024). Flowers of Aloe vera from Medieval manuscripts to Renaissance printed books. *Aldrovandiana. Historical Studies in Natural History*, 3(1), 151–185. <https://doi.org/10.30682/aldro2401m>
- Aloe dewinteri* | *PlantZAfrica*. (2017). Sanbi.org. <https://pza.sanbi.org/aloe-dewinteri>
- Aloe vera - Aloe vera* | *Plants* | *Kew*. (n.d.). [Www.kew.org. https://www.kew.org/plants/aloe-vera](https://www.kew.org/plants/aloe-vera)
- Aloe vera care guide*. (2019). The Stem. <https://thestem.co.uk/plant-academy/a-z-of-plants/aloe-vera-plant-care-guide>
- Aloe Vera Extract Market Size, Share, Growth & Trends [2030]*. (2026, March 2). [Www.fortunebusinessinsights.com](https://www.fortunebusinessinsights.com). <https://www.fortunebusinessinsights.com/aloe-vera-extract-market-103893>
- Amoo, S. O., Hlatshwayo, N. A., Doležal, K., & Olowoyo, J. O. (2022). Seed germination and in vitro propagation of three threatened endemic South African Aloe species. *South African Journal of Botany*. <https://doi.org/10.1016/j.sajb.2022.04.033>

- Arizaga, S., & Ezcurra, E. (2002). Propagation mechanisms in *Agave macroacantha* (Agavaceae), a tropical arid-land succulent rosette. *American Journal of Botany*, *89*(4), 632–641. <https://doi.org/10.3732/ajb.89.4.632>
- Carter, S., J, L. J., E, N. L., & C, W. C. (2026). The Open University. *Open.ac.uk*.
<https://oro.open.ac.uk/29013/1/walker1.mht>
- CHASE, M. W., & REVEAL, J. L. (2009). A phylogenetic classification of the land plants to accompany APG III. *Botanical Journal of the Linnean Society*, *161*(2), 122–127.
<https://doi.org/10.1111/j.1095-8339.2009.01002.x>
- Cousins, S. R., Witkowski, E. T. F., Pfab, M. F., Riddles, R. E., & Mycock, D. J. (2013). Reproductive ecology of *Aloe plicatilis*, a fynbos tree aloe endemic to the Cape Winelands, South Africa. *South African Journal of Botany*, *87*, 52–65.
<https://doi.org/10.1016/j.sajb.2013.02.174>
- Craven, J. (2022). *Aloe Vera*. The Daily Garden.
<https://www.thedailygarden.us/garden-word-of-the-day/aloe-vera>
- Cristiano, G., Murillo-Amador, B., & De Lucia, B. (2016). Propagation Techniques and Agronomic Requirements for the Cultivation of Barbados Aloe (*Aloe vera* (L.) Burm. F.)—A Review. *Frontiers in Plant Science*, *7*. <https://doi.org/10.3389/fpls.2016.01410>
- ESHUN, K., & HE, Q. (2004). Aloe Vera: A Valuable Ingredient for the Food, Pharmaceutical and Cosmetic Industries—A Review. *Critical Reviews in Food Science and Nutrition*, *44*(2), 91–96. <https://doi.org/10.1080/10408690490424694>
- ESS Subtopic 5.1: Soils. (2017). AMAZING WORLD of SCIENCE with MR. GREEN.
<https://www.mrgscience.com/ess-subtopic-51-soils.html>

Footo, C. (2015, February 26). *A history of Aloe vera: from the Arabian desert to that cream you use on your hands - BMC Series blog*. BMC Series Blog.

<https://blogs.biomedcentral.com/bmcseriesblog/2015/02/26/history-alo-vera-arabian-desert-cream-use-hands/>

Foster, N. (2017, September 20). *Aloe Vera Propagation: How To Remove Pups From the Mother Plant*. Joy Us Garden | Care, Propagation, and Pruning.

<https://www.joyusgarden.com/alo-vera-propagation-how-to-remove-pups/>

Grace, O. M., Buerki, S., Symonds, M., Forest, F., van Wyk, A. E., Smith, G. F., Klopper, R. R., Bjorå, C. S., Neale, S., Demissew, S., Simmonds, M., & Rønsted, N. (2015).

Evolutionary history and leaf succulence as explanations for medicinal use in aloes and the global popularity of Aloe vera. *BMC Evolutionary Biology*, 15(1), 29.

<https://doi.org/10.1186/s12862-015-0291-7>

Hamman, J. (2008). Composition and Applications of Aloe vera Leaf Gel. *Molecules*, 13(8), 1599–1616. <https://doi.org/10.3390/molecules13081599>

Haque, S. M., & Ghosh, B. (2013). High frequency microcloning of Aloe vera and their true-to-type conformity by molecular cytogenetic assessment of two years old field growing regenerated plants. *Botanical Studies*, 54(1).

<https://doi.org/10.1186/1999-3110-54-46>

Helena. (2025). *The light requirements of aloe vera – Gardentopia*. Gardentopia.eu.

<https://gardentopia.eu/the-light-requirements-of-alo-vera/>

Hopson, S. (2025). *Aloe Vera Plant: Care, Types, Growth, and Propagation*. The Rugs.

<https://the-rugs.com/blogs/how-to-guides-for-home-owners/alo-vera-plant-care-types>

- Horn, E. (2022, September 25). *How Much Direct or Indirect Sunlight Do Aloe Vera Plants Need?* Epic Gardening. <https://www.epicgardening.com/aloe-sunlight/>
- Isager Ahl, L., Pedersen, H. L., Jørgensen, B., Willats, W. G. T., Grace, O. M., Barnes, C. J., & Rønsted, N. (2023). Exploring the polysaccharide composition of plant cell walls in succulent aloes. *PLANTS, PEOPLE, PLANET*. <https://doi.org/10.1002/ppp3.10361>
- Jaiswal, S. K., Mahajan, S., Chakraborty, A., Kumar, S., & Sharma, V. K. (2021). The genome sequence of *Aloe vera* reveals adaptive evolution of drought tolerance mechanisms. *IScience*, *24*(2), 102079. <https://doi.org/10.1016/j.isci.2021.102079>
- Kashyap, N., Verma, I., Banyal, S. K., Singh, S., Sharma, S. K., & Bahadur, L. (2025). Cultivation, processing, nutritional value and phytochemicals in *Aloe vera*. *International Journal of Advanced Biochemistry Research*, *9*(11S), 94–100. <https://doi.org/10.33545/26174693.2025.v9.i11sb.6197>
- Kumar, S., Yadav, M., Yadav, A., & Yadav, J. P. (2017). Impact of spatial and climatic conditions on phytochemical diversity and in vitro antioxidant activity of Indian *Aloe vera* (L.) Burm.f. *South African Journal of Botany*, *111*, 50–59. <https://doi.org/10.1016/j.sajb.2017.03.012>
- Leech, J. (2020, May 15). *Aloe vera: 8 health benefits*. www.medicalnewstoday.com. <https://www.medicalnewstoday.com/articles/318591#bioactive-compounds>
- Martínez-Sánchez, A., López-Cañavate, M. E., Guirao-Martínez, J., Roca, M. J., & Aguayo, E. (2020). *Aloe vera* Flowers, a Byproduct with Great Potential and Wide Application, Depending on Maturity Stage. *Foods*, *9*(11), 1542. <https://doi.org/10.3390/foods9111542>
- McIntosh, J. (2025, June 23). *21 Types of Aloe Plants: Identification and Care Tips*. The Spruce. <https://www.thespruce.com/types-of-aloe-plants-4586709>

- Mensah, E. O., Adadi, P., Asase, R. V., Kelvin, O., Mozhdehi, F. J., Amoah, I., & Agyei, D. (2025). Aloe vera and its byproducts as sources of valuable bioactive compounds: Extraction, biological activities, and applications in various food industries. *PharmaNutrition*, 31, 100436. <https://doi.org/10.1016/j.phanu.2025.100436>
- Nejatzadeh, F. (2019). Data on growth and production of (*Aloe vera* L.) treated by different levels of vermicompost and nitrogen fertilizer. *Data in Brief*, 22, 709–715. <https://doi.org/10.1016/j.dib.2018.12.052>
- Old Farmer's Almanac. (2019, November 28). *Aloe Vera*. Old Farmer's Almanac. <https://www.almanac.com/plant/aloe-vera>
- Oldest completely preserved lily discovered*. (2019, July 9). Museum Für Naturkunde. <https://www.museumfuernaturkunde.berlin/en/museum/media/press/oldest-completely-preserved-lily-discovered>
- Pain, S. (2015, June 15). *How Aloe vera became a cure-all and cosmetic superstar*. New Scientist. <https://www.newscientist.com/article/mg22730301-200-how-aloe-vera-became-a-cure-all-and-cosmetic-superstar/>
- Ralls, E. (2019). *How To Use the Aloe Vera Plant*. Earth.com. <https://www.earth.com/earthpedia-articles/how-to-use-the-aloe-vera-plant/>
- Rathore, M. S., Chikara, J., Mastan, S. G., Rahman, H., Anand, K. G. V., & Shekhawat, N. S. (2011). Assessment of Genetic Stability and Instability of Tissue Culture-Propagated Plantlets of *Aloe vera* L. by RAPD and ISSR Markers. *Applied Biochemistry and Biotechnology*, 165(5-6), 1356–1365. <https://doi.org/10.1007/s12010-011-9352-6>

Royal Botanic Gardens, Kew. (n.d.). *Aloe vera (L.) Burm.f.* Plants of the World Online.

<https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:530017-1>

Silva, H., Sagardia, S., Ortiz, M., Franck, N., Opazo, M., Quiroz, M., Baginsky, C., & Tapia, C.

(2014). Relationships between leaf anatomy, morphology, and water use efficiency in *Aloe vera* (L) Burm f. as a function of water availability. *Revista Chilena de Historia Natural*, 87, 1–10. <https://doi.org/10.1186/S40693-014-0013-3>

Surjushe, A., Vasani, R., & Saple, D. (2008). *Aloe vera*: A short review. *Indian Journal of Dermatology*, 53(4), 163. <https://doi.org/10.4103/0019-5154.44785>

The Shocking Truth About Aloe Vera (And How to Remove the Latex). (2024). Kylevialli.com.

<https://www.kylevialli.com/blog/the-truth-about-aloe-vera>

Tuttle , C. (2021, May 6). *How to Water Succulent Plants | Succulents and Sunshine*.

[Www.succulentsandsunshine.com](http://www.succulentsandsunshine.com).

<https://www.succulentsandsunshine.com/how-to-water-succulent-plants/>

United States Department of Agriculture. (2024). *USDA Plants Database*. [Usda.gov](https://plants.usda.gov).

<https://plants.usda.gov/plant-profile/ALVE2>

You are being redirected... (2024). [Seair.co.in](https://www.seair.co.in).

<https://www.seair.co.in/blog/the-rise-of-aloe-products-a-closer-look-at-aloe-vera-export-d-ata.aspx>