

BOTANICAL DESCRIPTION, VARIETIES, AND BIOLOGICAL PROPERTIES OF CUCUMBER

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Abstract. This article provides a comprehensive overview of the botanical description, varietal diversity, and biological properties of cucumber (Cucumis sativus L.). The morphology of the root system, stem, leaves, flowers, and fruits is described in detail. Modern classifications of varieties, including gynoecious and parthenocarpic hybrids for open field and protected cultivation, are presented. Special attention is given to the biological requirements of the crop for environmental factors such as temperature, humidity, and light, as well as resistance to biotic stresses based on recent genomic studies. The article is intended for researchers, agronomists, and students in the field of horticulture and plant sciences.

Аннотация. В данной статье представлен всесторонний обзор ботанического описания, сортового разнообразия и биологических свойств огурца (Cucumis sativus L.). Подробно описаны морфология корневой системы, стебля, листьев, цветков и плодов. Освещены современные классификации сортов, включая гинецийные и партенокарпические гибриды для открытого и защищенного грунта. Особое внимание уделено биологическим требованиям культуры к факторам внешней среды (температура, влажность, свет), а также устойчивости к биотическим стрессам на основе данных современных геномных исследований. Статья предназначена для научных сотрудников, агрономов и студентов в области horticulture и растениеводства.

Keywords: Cucumis sativus, cucumber, botanical description, morphological traits, cucumber varieties, parthenocarpy, gynoecious hybrids, biological properties, disease resistance, abiotic stress tolerance, fruit development.

Ключевые слова: Cucumis sativus, огурец, ботаническое описание, морфологические признаки, сорта огурца, партенокарпия, гинецийные гибриды, биологические свойства, устойчивость к болезням, толерантность к абиотическим стрессам, развитие плодов.

Introduction. Cucumber (Cucumis sativus L.) is one of the most widely cultivated and economically significant vegetable crops globally, belonging to the Cucurbitaceae family. Originating from the Indo-Gangetic plains of India, cucumber has been cultivated for over 3,000 years and has spread to every continent, adapting to diverse climatic conditions . It is a diploid species (2n = 2x = 14) with a small genome size of approximately 367 Mb, making it a model organism for studying sex determination, vascular biology, and genome evolution within the Cucurbitaceae family . China is the world's largest producer, accounting for over 79% of global output, while the United States, Turkey, and Russia also represent major production centers .

The fruit is valued for its high water content (up to 96%), low-calorie profile, and presence of bioactive compounds such as cucurbitacins, which exhibit anti-inflammatory and potential anti-cancer properties . While generally considered a warm-season crop requiring

specific environmental conditions, the development of early-maturing and parthenocarpic varieties has enabled its cultivation in temperate and even subarctic regions . This article synthesizes current knowledge on the botanical characteristics, variety classification, biological properties, and genetic resources of cucumber, drawing from classical botanical literature and contemporary genomic research.

Main part. The cucumber plant develops a taproot system that is highly branched but relatively shallow. While the primary root can penetrate up to 1 meter in depth under optimal soil conditions, the majority (approximately 85-90%) of the root mass is concentrated within the top 20-25 cm of the soil profile . Lateral roots can spread horizontally up to 1.5 meters from the plant base. A distinctive feature of cucumber is its ability to develop adventitious roots from the stem nodes when they come into contact with moist soil, a characteristic often exploited in commercial production through hilling or trellising systems . The root system is highly sensitive to low temperatures; soil temperatures below 16°C significantly inhibit water and mineral uptake, primarily due to reduced root hair activity and increased viscosity of cellular membranes .

Stem (Shoot). The stem is prostrate, branched, and angular with a rough texture due to the presence of white hispid trichomes (epidermal hairs) . The growth habit is indeterminate, with the main stem producing lateral branches (first-order, second-order) from leaf axils . The degree of branching is variety-dependent, classified into weak (1-4 lateral shoots), medium (5-8 lateral shoots), and strong (more than 8 lateral shoots) types . Stem length varies significantly: open-field determinate varieties range from 1-1.5 meters, while greenhouse indeterminate varieties can exceed 5 meters in length . The plant climbs via simple, unbranched tendrils that coil around supports.

Leaves. Leaves are arranged alternately along the stem. The leaf blade is broad, cordate (heart-shaped), and palmately 3-5 lobed, measuring 7-20 cm in both length and width . The leaf margin is dentate (toothed), and the surface is pubescent (covered with short bristles). Leaf surface texture, ranging from smooth to wrinkled, and color intensity are variety-specific traits often associated with photosynthetic efficiency and disease tolerance .

Flowers and Inflorescence. Cucumber is typically monoecious (both male and female flowers borne on the same plant), although gynoecious (all female flowers) and androecious (all male flowers) lines exist and are utilized in hybrid seed production . Male (staminate) flowers are smaller, yellow, and usually borne in clusters (fascicles) of 5-7 in leaf axils. Female (pistillate) flowers are generally solitary, possess an inferior ovary (which develops into the fruit), and are distinguished by a swollen, miniature fruit shape at the base of the corolla .

Floral biology is characterized by a short anthesis period: male flowers wither 1-2 days after opening, while female flowers remain receptive for 3-4 days . Cucumber is an entomophilous (insect-pollinated) crop, primarily requiring honeybees for pollen transfer. However, the development of parthenocarpic varieties, which set fruit without fertilization, has revolutionized greenhouse production, although such fruits are typically seedless . The sex expression is regulated by hormonal balance, particularly ethylene, which promotes female flower development .

Fruit and Seeds. The fruit is a pepo (a type of berry with a hard rind), typically cylindrical to oblong in shape. Commercial consumption occurs at the immature stage (10-30 days post-anthesis). Fruit size varies enormously by variety: from small pickling types (5-10 cm) to long European greenhouse types (up to 50-70 cm) . The fruit surface may be smooth (common in

European greenhouse types), warty (verrucose), or covered with spines (trichomes), which are either black or white, a key distinguishing trait between the two major variety groups (see Section 2.2) .

Internally, the fruit contains 3-5 locules (seed cavities) filled with fleshy, gelatinous placental tissue. At botanical maturity (seed stage), the fruit turns yellow to orange-brown, and the skin becomes tough . Seeds are small, white to pale yellow, ovoid, and flat, with 100-400 seeds per fruit. The thousand-seed weight ranges from 16-35 grams. A notable physiological trait is that maximum germination and yield are often achieved not with fresh seed but with seeds stored for 2-3 years, as this allows for after-ripening processes that break dormancy and reduce the production of male flowers .

Varieties and Classification.The vast genetic diversity of cucumber has been organized into distinct ecotype groups based on geographic origin, morphology, and end-use. The two primary varietal groups are the North China (or华北型) type and the South China (or华南型) type, from which most modern cultivars are derived .

Beyond these regional types, breeding has produced specialized lines. Gynoecious hybrids are widely adopted as they concentrate flowering and fruiting, significantly increasing early yield . Parthenocarpic varieties are essential for protected cultivation (polytunnels and greenhouses) where insect pollinators may be excluded . Recent breeding efforts focus on incorporating resistance genes against major biotic stresses such as Downy Mildew (Pseudoperonospora cubensis), Powdery Mildew (Podosphaera xanthii), Cucumber Mosaic Virus (CMV), and Fusarium wilt .

Temperature. Cucumber is a thermophilic crop with specific cardinal temperature thresholds. The minimum temperature for seed germination is 12-13°C, though germination is optimal between 25-30°C, occurring in 5-6 days . For vegetative growth and fruit set, the optimal day temperature is 25-32°C, while optimal night temperature is 16-18°C . Prolonged exposure to temperatures below 12-15°C retards growth, induces leaf chlorosis, and reduces root function, ultimately leading to plant senescence. High temperatures above 40°C can be tolerated if relative humidity and soil moisture are adequately maintained .

Water and Humidity. Cucumber has a high water requirement due to its shallow root system and large, thin leaves that facilitate high transpiration rates. Optimal fruit production requires consistent soil moisture at field capacity. Water stress leads to reduced fruit set, increased incidence of blossom-end rot, and the development of bitter compounds (cucurbitacins) in the fruit . The crop also demands high atmospheric humidity (60-80% RH), although excessive humidity without air circulation promotes fungal diseases such as Downy Mildew and Botrytis.Cucumber is generally classified as a quantitative short-day plant, meaning it flowers earlier under shorter photoperiods (8-10 hours). However, modern cultivars, particularly those for greenhouse production, are day-neutral or adapted to long-day conditions, allowing for high yields in high-latitude summer seasons .

Genetics and Resistance. The cucumber genome's availability has accelerated the identification of quantitative trait loci (QTLs) and genes associated with disease resistance. For example, the discovery of the dm (downy mildew) and pm (powdery mildew) resistance QTLs has allowed marker-assisted selection (MAS) to rapidly introgress resistance into elite germplasm without compromising fruit quality . The global gene pool is categorized into the primary (GP-1, C. sativus var. sativus and var. hardwickii), secondary (GP-2, C. sativus f.

sclerocarpus), and tertiary (GP-3, other Cucumis species like C. hystrix) gene pools. The tertiary pool is a valuable, though underutilized, source for novel resistance alleles against emerging pathogens .

Conclusion. Cucumber (Cucumis sativus) is a morphologically diverse and economically critical horticultural species. Its botanical characteristics—a shallow taproot with adventitious rooting ability, a climbing indeterminate stem, monoecious floral biology requiring pollination (or parthenocarpy for protected culture), and a pepo fruit consumed immature—define its cultivation requirements. The crop's global distribution has led to the development of distinct ecotypes (North China, South China, European greenhouse, and American slicers), each with specific traits for fresh market or processing use.Biologically, cucumber is highly sensitive to abiotic stresses, particularly temperatures below 15°C and inconsistent soil moisture. However, classical breeding and modern genomic tools have successfully incorporated resistance to major biotic stresses (Downy Mildew, Powdery Mildew, and viruses) and manipulated sex expression (gynoecy) and fruit set (parthenocarpy). Future research will likely focus on exploiting the tertiary gene pool of wild relatives via advanced techniques such as genome editing (CRISPR/Cas9) to enhance resilience to climate change and emerging pathogens, ensuring sustainable production for global food systems

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