Opuntia

Opuntia ficus-indica L., Cactaceae

A drought- and saline-resilient crop of WaterMellon project

01 History and origin

- **Native to central Mexico**, domesticated over 9,000 years ago, likely from *O. streptacantha* and *O. megacantha*.
- **Spread globally** through Spanish colonization for its fruit, natural dye (derived from the cochineal mealybug), and role in preventing scurvy.
- Cultivated on over **100,000 ha globally**, particularly in Mexico, Italy, Spain, Israel, Chile, Algeria, Tunisia, Morocco and Brazil.

02 Morphological Characteristics

- **Lifespan:** 80 to 100 years under favorable conditions, 20 to 30 years for commercial cultivation.
- **Ploidy:** Cultivated varieties are typically octoploid (2n = 88).
- **Growth:** Perennial cactus with a tree-like growth, reaching 3–7 m in height.
- **Stem:** Lignified, cylindrical stem, dark brown, green or gray, up to 45 cm tall and 20 cm wide.
- **Cladodes (Pads):** Mostly elliptic, occasionally obovate, bright green, with or without glochids.
- **Pericarpel:** Cylindrical to conic.
- **Flowers:** Yellow to orange, 6–7 cm in diameter, with numerous stamens. Diurnal anthesis (day-opening), up to 10 flowers per cladode, usually located along the cladode's apical margin.

- **Fruits:** Oblong (5–10 cm), red/yellow/purple, with 40–60 areoles.
- **Seeds:** 5 mm in diameter, numerous per fruit, surrounded by mucilage.
- **Roots:** Shallow lateral roots predominate, with up to 87% of biomass located in the topsoil. Lateral spread reaches 1.8 m in one year. Roots account for 13% of total biomass. Root-to-cladode biomass ratio decreases under water stress.
- **Reproduction**: Sexually and asexually (vegetative propagation via cladodes).

03 Soil and climate requirements

- **Soil:** Thrives in sandy-loam to loamy soils. Requires well-drained soils and is highly susceptible to waterlogging. Although shallow-rooted, it benefits from moderate soil depth (≈40 cm or more).
- **pH Range**: Tolerates pH 5.5 to 8.5 (optimal: slightly acidic to neutral).
- **Climate:** Optimal temperature range is 18–26 °C. Tolerates >40 °C in summer. Withstands brief frosts down to −3 °C. Grows from sea level up to 2,600 m a.s.l. Requires full sunlight; shade reduces fruit and cladode production.
- **Rainfall:** Best suited in semi-arid to arid climates. Minimum requirement: 250–300 mm/year (can survive with <250 mm). Optimal requirement : 350–600 mm/year.
- **Salinity:** Sensitive at the seedling stage; mature plants tolerate moderate salinity.
- **CAM photosynthesis:** Crassulacean Acid Metabolism enables high water-use efficiency. Survives 6–10 months of drought by using stored water in its cladodes.

04 Fertilization & Cultivation

- **Fertilization:** Requires nitrogen (N), phosphorus (P), and potassium (K). Moderate fertilization (e.g., 50–100 kg ha^{-1} N and 50 kg ha^{-1} P_2O_5) increases productivity by 200–300%. Boron (B), calcium (Ca), magnesium (Mg), and iron (Fe) also enhance growth and yield. Combining organic fertilizers (e.g., 100 t ha^{-1} manure) with chemical inputs further improves yield.
- **Planting:** Cladodes (pads) are planted directly in the soil. Young cladodes require minimal irrigation (approx. 10 L per plant).
- **Density:** Dense, bushy planting enhances light interception by increasing canopy cover and reducing light loss to the soil surface.
- **Weed management**: Weed control is often achieved via organic mulch or inter-row tillage.
- **Harvesting:** Mostly manually, due to the delicate nature of fruit and the need to avoid damage. Mechanical harvesting techniques are applied experimentally in high-density plantations or for cladode biomass.

05 Diseases & Pests

- **Insects**: *Cactoblastis cactorum*, *Dactylopius* spp., *Ceratitis capitata*.
- **Pathogens:** *Botrytis cinerea*, *Alternaria* spp., *Pectobacterium* spp. **High disease risk** under humid conditions or with poor harvesting practices.

06 World production & Market Export and Import value

- **Global Production:** Mexico is the largest producer with 300,000–500,000 tons/year (44% of global production), covering 50,000–70,000 ha.
- **Other producers:** **Italy:** 78,000–87,000 tons/year, 7,000–8,300 ha, **South Africa:** ≈ 15,000 tons/year, 1,500 ha, **Chile:** 934 ha, **Peru:** ≈ 5,000 tons/year, **Argentina:** 7,500 tons/year, **USA:** 120 ha.
- **Economic Importance:** In Mexico, average income: €1,280/ha. In Italy, higher at ≈ €1,658.88/ha, due to quality, seasonal availability, and export value.

07 Uses of the Opuntia Tree

- **Food industry:** **Fruits** (prickly pears) are consumed fresh or processed into juices, jams, wines, marmalades, and syrups. **Cladodes** (nopalitos) are eaten as vegetables in Mexico and Latin America, often fresh, cooked, or pickled. They are also used as livestock forage, especially in arid regions. With nitrogen fertilization their protein content can reach 9%, making them comparable to conventional fodder.
- **Nutraceutical & medicinal uses:** Rich in antioxidants such as betalains, phenolic compounds, and vitamin C, as well as amino acids and dietary fiber, making it a valuable source of bioactive extracts for nutraceutical applications. Medicinal uses include anti-inflammatory, anti-ulcerogenic, hypoglycemic, hypolipidemic and wound-healing properties.
- **Environmental & Industrial Uses:** By-products like peels and seeds are valuable for the biofuel, dye, or cosmetic industries. Cultivation contributes to land rehabilitation and carbon sequestration, enhancing environmental sustainability.

Opuntia ficus-indica is exceptionally well adapted to arid and semi-arid environments, capable of thriving on degraded soils and withstanding prolonged droughts, making it one of the few productive crops under such challenging conditions. Its cultivation on extensive land areas worldwide, especially in drought-prone regions, highlights its critical role in sustainable agriculture, serving purposes ranging from food and forage production to soil restoration and climate resilience.

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