

Important Perennial Crops (grasses and herbaceous) for marginal lands

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**KAPES
CRES**

CENTRE FOR RENEWABLE
ENERGY SOURCES AND SAVING

Midas

MARGINAL LANDS, INDUSTRIAL CROPS
AND INNOVATIVE BIO-BASED VALUE CHAINS



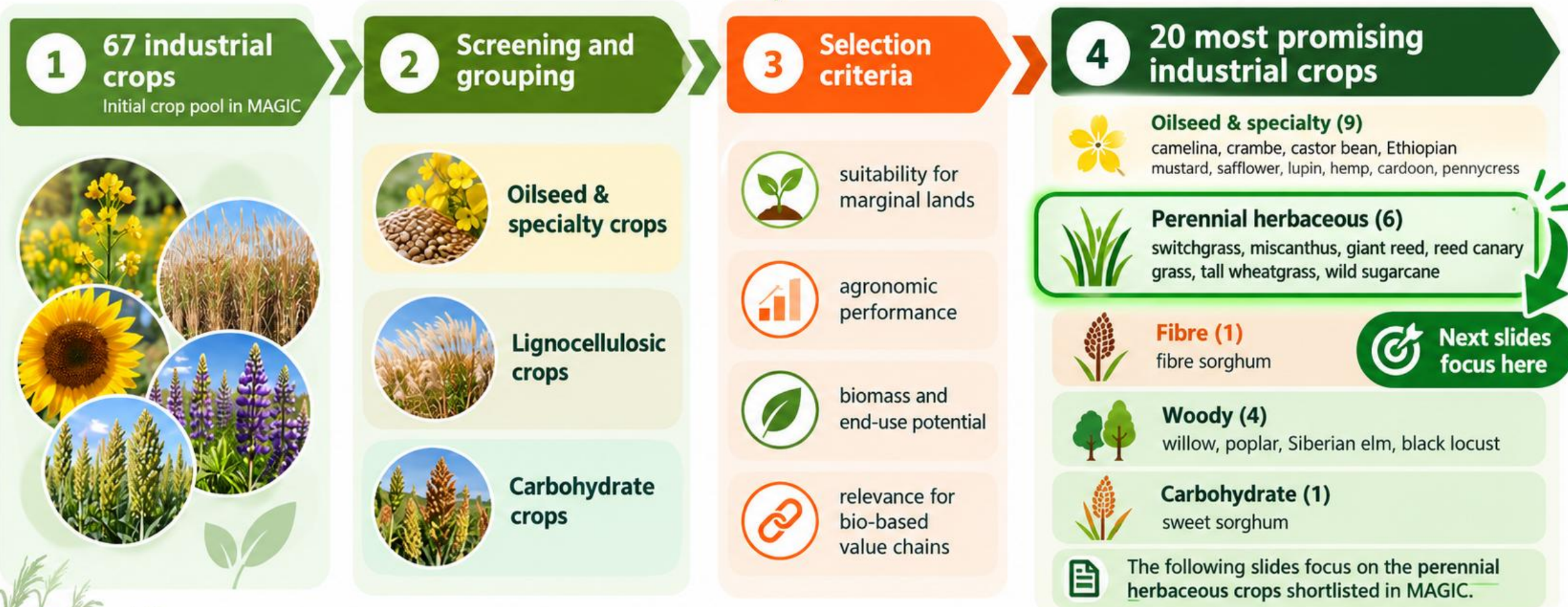
Funded by
the European Union

This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101082070.



Selection of the most promising industrial crops in MAGIC

From 67 candidate crops to a shortlist of 20



Some crops have multiple uses and appear in more than one functional group in the MAGIC classification; the final shortlist contains 20 unique crops.

Switchgrass

(*Panicum virgatum* L.)

Contents

- Crop description
- Origin of the crop
- Soil and climate preferences
- Cultural protocol
- Harvesting
- Uses

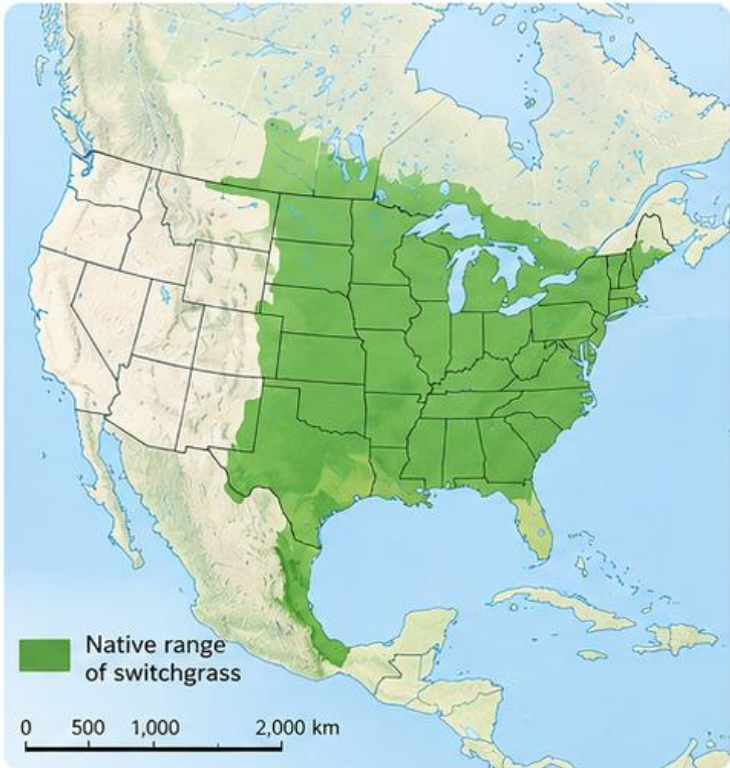


Origin and ecotypes of Switchgrass

(*Panicum virgatum* L.)



Origin & native range



- Native warm-season C4 perennial grass of North America.
- Historically important in the North American tallgrass prairie.



Two major ecotypes

LOWLAND



- Taller & coarser
- Broader leaves
- Fewer but larger tillers
- Later flowering
- Higher biomass potential
- Adapted to wetter or floodplain habitats
- Mostly tetraploid

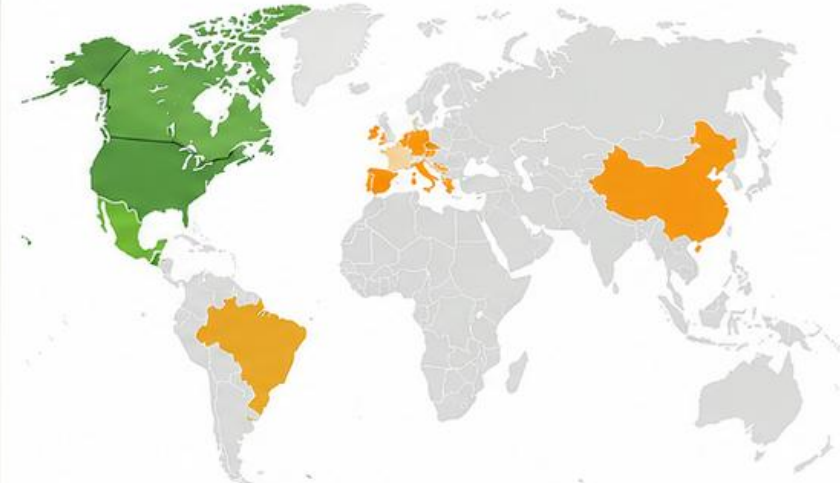
UPLAND



- Shorter & finer
- Narrower leaves
- More tillers
- Earlier flowering
- Greater winter hardiness
- Adapted to drier/cooler northern habitats
- Tetraploid or octoploid



Cultivation & evaluation beyond the native range



- Native range (North America)
- Introduced / cultivated or evaluated

- Introduced and evaluated as a biomass/energy crop in Europe, Asia and South America.
- European field research includes Greece, Italy, Germany, the Netherlands and the United Kingdom, with later trials also in Portugal.
- It has also been evaluated in China.
- **Outside North America, switchgrass is mainly an introduced biomass/energy crop and research crop.**

Switchgrass crop description

(*Panicum virgatum* L.)



Perennial warm-season C4 grass



Family: Poaceae



Erect, tufted growth habit; height commonly ~1–3 m depending on ecotype and conditions



Lowland types are generally taller and coarser; upland types are shorter and finer.



Small seeds



Narrow linear leaves and a loose, open panicle



Long-lived crop, established from seed and able to regrow annually from the crown/rhizomes



Short rhizomes and an extensive **deep root system**; rooting depths >3 m have been recorded



Soil and climate preferences and cultivation practices of Switchgrass (*Panicum virgatum* L.)



Soil and climate preferences

- **Warm-season perennial C4 grass** adapted to temperate climates.
- Performs best in **full sun** and tolerates hot summers.
- **Cold hardy**; widely adapted in temperate regions.
- Best on **moderately deep to deep soils**.
- Grows on **sandy loam to clay loam soils**; tolerates a wide range of textures.
- Optimal **soil pH** generally **6.0–8.0**, but it can tolerate slightly more acidic soils.
- **Tolerates drought** once established; lowland ecotypes prefer wetter sites, while upland ecotypes are better adapted to drier/cooler sites.
- Can be grown on **marginal lands**, but prolonged **waterlogging** and very **heavy compacted soils** are less suitable.



Cultivation practices

- 1  **Establishment**
Sow in spring when soils are warm (about 10–12°C or higher).
- 2  **Seedbed**
Firm, fine, weed-free seedbed; shallow sowing around 1–2 cm.
- 3  **Weed control**
Very important during the first year; mowing or selective control may be needed.
- 4  **Fertilisation**
Apply P and K according to soil test; avoid nitrogen at seeding; moderate N after establishment if needed.
- 5  **Water**
Irrigation may help establishment in dry areas, but established stands are relatively drought tolerant.
- 6  **Crop development**
Establishment is usually slow in year 1; full productivity is reached after establishment.
- 7  **Harvest**
For biomass, harvest once per year after senescence/dry-down to improve feedstock quality and nutrient recycling.



Growth stages and field appearance



Seeds



Early stages



Flowering



Lodging



Harvesting time

Harvesting practices of Switchgrass (*Panicum virgatum* L.)



Key harvesting practices

1



Harvest once per year

Biomass is commonly harvested once per year after senescence or after a killing frost.

2



Timing

Harvest is often carried out in **late autumn or winter**. Delayed harvest can improve feedstock quality by lowering moisture, ash and nutrient content, but may reduce yield.

3



Equipment

Conventional hay equipment can be used.

4



Typical sequence

Mowing → raking/windrowing → baling, or chopping/collection depending on the supply chain.

5



Stubble height

Leave a stubble of about 7.5–15 cm to protect crowns and support regrowth.

6



Field conditions

Prefer dry or frozen field conditions to reduce rutting and damage to soil and crowns.

7



System considerations

For dedicated biomass systems, a single post-senescence harvest is usually preferred; earlier or dual harvests may be used when forage is also a goal.



Harvest sequence and field appearance



Seeds



Early stages



Flowering



Lodging



Harvesting time



Mowing



Raking / windrowing



Baling



Storage / transport

Uses of Switchgrass (*Panicum virgatum* L.)



Bioenergy and biofuels

- Solid biofuels for heat and electricity (pellets, briquettes, combustion).
- Production of advanced biofuels (cellulosic ethanol, biomethane, synthetic fuels).
- Suitable lignocellulosic feedstock with high yields and low input requirements.



Pellets



Combustion



Advanced biofuels



Biobased products

- Bioplastics and biochemicals (e.g. platform chemicals such as xylitol, furfural, organic acids).
- Natural fibres and composites (e.g. for automotive or construction applications).
- Particle boards and other wood-fibre based materials.



Bioplastics and biochemicals



Particle boards and wood-based materials



Natural fibres and composites



Forage and animal uses

- Grazing (mainly in early growth stages) and conserved as hay or silage.
- Useful for extensive livestock systems, with moderate nutritive value.



Grazing



Hay bales



Environmental and other uses

- Erosion control and soil conservation (deep and dense root system, improves soil structure and organic matter).
- Reclamation of marginal and degraded lands.
- Habitat provision for wildlife and enhancement of biodiversity.
- Carbon sequestration through long-lived perennial stands.



Soil conservation and land reclamation



Habitat provision and biodiversity



Miscanthus (*Miscanthus* × *giganteus*)

Contents



1

Crop description



2

Origin of the crop



3

Soil and climate preferences



4

Cultural protocol



5

Harvesting



6

Uses



Crop description of *Miscanthus* × *giganteus*



Perennial C4 grass

Perennial warm-season C4 grass; family Poaceae.



Sterile hybrid

Sterile allotriploid natural hybrid, $2n = 3x = 57$; produces no viable seed in the standard clone.



Vegetative propagation

Propagated by rhizomes or micropropagated plantlets.



Tall, erect growth

Tall, erect, cane-like stems forming dense clumps; typically around 2–4 m depending on environment.



Leaves and inflorescences

Long, broad linear leaves and large feathery panicles appearing in late summer–autumn.



Perennial rhizome system

Underground perennial rhizome/root system; shoots senesce in winter and regrow each spring.



Long-lived crop

Commonly maintained for many years, with efficient internal nutrient recycling.



Miscanthus panicles



Miscanthus rhizomes

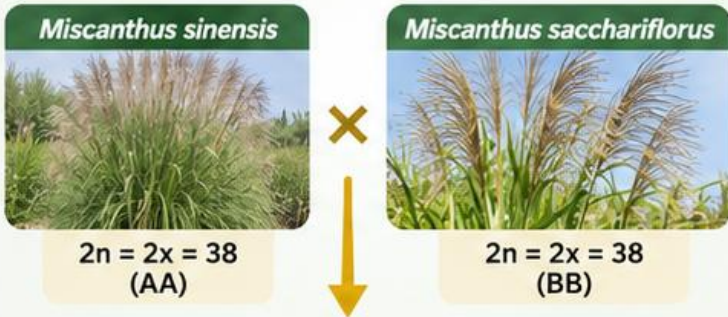
Miscanthus × giganteus

Origin and cultivation area



1 Hybrid origin

- *Miscanthus × giganteus* is a sterile interspecific hybrid between *Miscanthus sinensis* and *Miscanthus sacchariflorus*.
- It originates in East Asia, especially Japan.
- The standard clone is sterile and triploid (allotriploid) with $2n = 3x = 57$ chromosomes.



Miscanthus × giganteus
Sterile, triploid (allotriploid)
 $2n = 3x = 57$
(AAB)

2 Historical timeline

- Before 1935**
Origin in East Asia
Natural hybridization between *M. sinensis* and *M. sacchariflorus* in East Asia, especially Japan.
- 1935**
Introduction to Europe
Introduced from Japan to Denmark in 1935 by Aksel Olsen, where it was established and propagated as a vegetative clone.
- 1980s onward**
Wider evaluation in Europe
Extensive field trials and cultivation as a biomass crop across Europe from the 1980s onward.
- 1990s onward**
Global spread
Subsequently evaluated and cultivated in North America and other temperate regions worldwide.

3 Cultivation and evaluation area

- Originally from **East Asia** (especially Japan), *Miscanthus × giganteus* is now widely cultivated and evaluated in Europe and North America, with additional trials and cultivation in other temperate regions.
- In **Europe**, field trials and cultivation extend from Mediterranean regions to southern Scandinavia.



- Origin (Japan, East Asia)
- Main cultivation and evaluation region (Europe)
- Major cultivation/evaluation region (North America)
- Other temperate regions with trials or cultivation
- Not reported or limited information

Soil and climate preferences, cultivation practices of *Miscanthus* × *giganteus*



Soil preferences

- Prefers **deep, well-drained soils**; loam, silt loam and light-to-medium clay soils are generally suitable.
- Can grow on a **wide range of soils**, including some marginal lands, but **prolonged waterlogging should be avoided**.
- **Medium to light soils** favour rhizome establishment and early growth.
- Performs best in slightly acidic to neutral soils (about **pH 5.5–7.5**), although it is relatively adaptable.



Climate preferences

- Perennial C₄ grass best adapted to **temperate climates with warm growing seasons**.
- **Good winter hardiness** once established; low soil temperatures and late spring frosts can reduce establishment success.
- Good biomass production requires **adequate moisture**; annual rainfall around **600–800 mm** is generally favourable.
- **Prolonged summer drought** can reduce yield, especially during establishment.



Cultivation practices

- **Establish in spring** using rhizomes or micropropagated plantlets, after risk of severe frost and when soil temperature is above about **10 °C**.
- Good seedbed preparation and strong **weed control** are essential during the first 1–2 years.
- Typical planting densities are about **10,000–20,000 plants ha⁻¹** depending on planting material and site.
- **Irrigation** may support establishment in dry regions, but mature stands are more drought tolerant.
- **Fertiliser demand is generally low**; often little or no N is needed in the first 1–2 years unless soils are poor, with later inputs based on soil testing.
- Full productivity is usually reached from **year 2–3 onward**, and stands may remain productive for **15–20 years or more**.



Miscanthus plantation in central Greece (source: CRES)

Harvesting of *Miscanthus × giganteus*



Harvest time

- For dry biomass and solid fuel uses, harvest is usually carried out **from late winter to early spring**, after full senescence.
- Delayed harvest allows leaf fall and nutrient translocation to the rhizomes, lowering moisture, ash and mineral content.
- In some systems, an earlier autumn or winter harvest may be chosen for anaerobic digestion or when higher biomass yield is prioritised.



Harvesting systems

- **Two-step dry harvest:** mowing or cutting, swathing / windrowing, then baling (round or square bales).
- **Single-pass harvest:** a forage harvester chops the biomass and loads it directly into trailers.
- A cutting height of about **10–20 cm** is commonly maintained to support stand persistence and regrowth.



Practical notes

- Dry standing biomass is easier to store and handle; moisture at harvest is often below about **20–25%** for delayed harvests.
- Delayed harvest improves fuel quality but can reduce harvestable yield because of leaf loss and weathering.
- Bales or chips should be stored under dry, protected conditions.



Plantation at the end of autumn in Greece.



Harvesting of dry biomass.

Main uses of *Miscanthus × giganteus*



Solid bioenergy

- Combustion for heat and power generation.
- Pellets, briquettes and chips for boilers and district heating.
- Suitable lignocellulosic feedstock with high dry matter yields.



Biofuels and biorefinery

- Feedstock for cellulosic ethanol and other advanced biofuels.
- Used in anaerobic digestion / biogas and biomethane systems, depending on harvest regime.
- Source of cellulose, hemicellulose and platform molecules in integrated biorefineries.



Biobased materials

- Particleboards, fibreboards and biocomposites.
- Pulp and paper, moulded fibre products and packaging.
- Insulation panels and other bio-based construction materials.



Agricultural and other uses

- Animal bedding and stable litter.
- Mulch, horticultural uses and thatching.
- Additional value in diversified bioeconomy supply chains.



Giant reed (*Arundo donax* L.)

Giant reed (*Arundo donax* L.) is a tall, perennial grass native to the Mediterranean region, widely recognised for its high biomass productivity, adaptability to diverse environments and multiple uses, including bioenergy and biobased products.



Crop
description



Origin
of the crop



Soil and climate
preferences



Cultural
protocol



Harvesting



Uses

Giant reed (*Arundo donax* L.) – Crop description



Mature stand of giant reed
(*Arundo donax* L.)



Rhizomes and underground buds



Culms (stems)



Inflorescence (panicle)



Botanical identity

Perennial, tall, rhizomatous grass in the family Poaceae.



Growth habit and size

Erect canes 3–6(–8) m tall, diameter 1–4 cm, forming dense clumps from extensive rhizomes.



Leaves

Long, linear leaves (2–6 cm wide, 20–70 cm long), green to grey-green.



Inflorescence

Large, feathery panicles (20–60 cm), purplish to silvery, produced in late summer to autumn.



Reproduction

Mainly vegetative via rhizomes; also by seed (flowering usually occurs in short-day conditions).



Life cycle

Perennial (10–20+ years) with high annual biomass production due to vigorous clonal growth.



Key features

- Robust perennial grass with extensive rhizomes.
- High biomass productivity, rapid regrowth after cutting.
- Adapted to a wide range of environments, especially warm-temperate and Mediterranean regions.
- Tolerant to drought, flooding and salinity.

Giant reed (*Arundo donax* L.) – Origin and cultivation area



Origin

- Native to Asia, with a centre of origin in South and East Asia (e.g., India, China, Southeast Asia).
- Naturalised for centuries around the Mediterranean Basin, the Middle East and parts of Africa.
- Introduced to many regions worldwide and now cultivated on all continents with suitable climates.



Giant reed along a riverbank (naturalised population) in the Mediterranean region.



Global distribution and cultivation area



Native range (Asia)



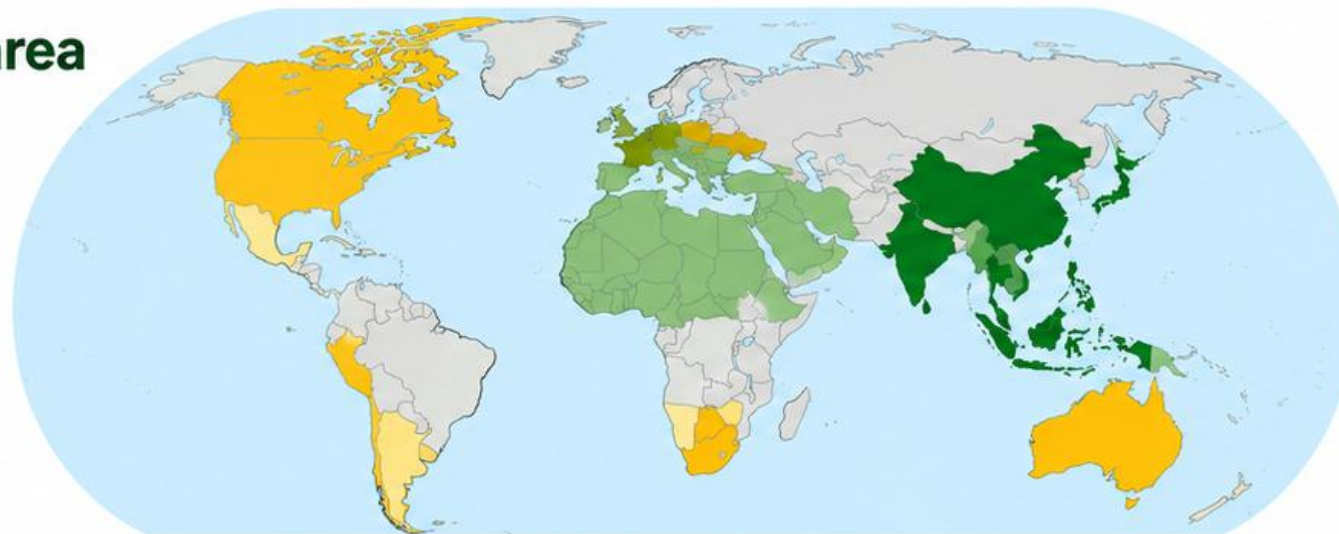
Long-standing cultivation /
naturalised (Mediterranean, Middle East, Africa)



Cultivated / naturalised in other regions



Limited / local presence



Main cultivation regions (examples)

- **Mediterranean region:** Spain, Italy, France, Greece, Turkey, North Africa (e.g. Algeria, Morocco, Tunisia).
- **Middle East:** widely cultivated for biomass and traditional uses.
- **Asia:** native and cultivated (China, India, Pakistan, Iran).
- **Other regions:** introduced and cultivated in North and South America (USA, Brazil, Argentina), Australia and parts of sub-Saharan Africa.

Giant reed (*Arundo donax* L.) – Soil and climate preferences & cultivation protocol



Soil preferences

- Adapted to a wide range of soils, from sandy loams to clay loams.
- Prefers deep, well-drained to moderately moist soils, but tolerates poor fertility and degraded land.
- Tolerates salinity and occasional waterlogging; performs best on neutral to slightly alkaline soils.



Climate preferences

- Best suited to warm-temperate, Mediterranean and subtropical climates.
- High biomass production under warm growing seasons; optimal growth in roughly 20–30 °C conditions.
- Drought tolerant after establishment thanks to deep roots/rhizomes, but establishment benefits from moisture or supplementary irrigation.
- Rhizomes survive mild winters, while shoots are sensitive to severe frost.

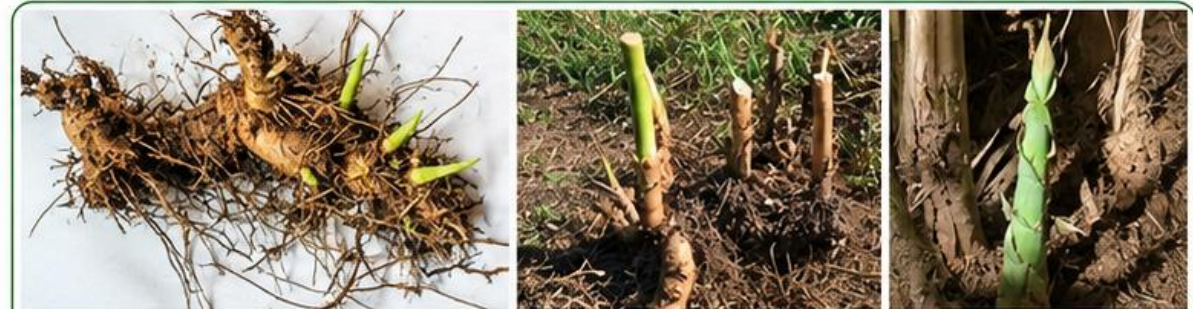


Cultivation protocol

- Establish using rhizomes, stem cuttings or nursery plantlets.
- Plant in spring after frost, typically at 10–20 cm depth and about 1–2 plants m⁻².
- Prepare a clean seedbed; weed control is essential in the first year.
- Apply modest fertilisation if needed; irrigation is mainly useful during establishment or in very dry sites.
- First substantial harvest usually from year 2 onward; stands can remain productive for 10–20 years.



Giant reed plantation in central Greece (source: CRES)



Rhizome propagation

Harvesting of giant reed (*Arundo donax* L.)

- ➔ Harvest is usually carried out after autumn senescence and often in winter to early spring, when canes are dry and nutrients have moved back to the rhizomes.
- ➔ Delayed harvest lowers moisture and ash-forming minerals, improving fuel quality and storage stability.
- ➔ Common systems include direct chopping with a forage harvester and trailer, or cutting/windrowing followed by baling.
- ➔ First substantial harvest is usually from the 2nd year onward; stands can then be harvested annually for many years.
- ➔ Biomass is commonly handled as chips or round bales and stored in dry conditions before use.

Winter giant reed stand
(reference photo based on user
material / CRES)



Giant reed bales



Mechanized harvest with forage harvester and trailer



Uses of giant reed (*Arundo donax* L.)

- ➔ Giant reed is a high-yield perennial non-food biomass crop used mainly as lignocellulosic feedstock.
- ➔ It is suitable for solid bioenergy applications such as combustion, pellets, briquettes and combined heat and power.
- ➔ It can also be used in biorefineries for bioethanol, biogas/biomethane and other bio-based products.
- ➔ Fibres and cellulose can be used for pulp, paper, particleboards, insulation materials and biocomposites.
- ➔ Beyond biomass, giant reed is studied for phytoremediation, soil rehabilitation and biomass production on marginal or saline land.

Solid bioenergy



Advanced biofuels and biogas



Pulp, paper and biomaterials



Phytoremediation and environmental uses



Tall wheatgrass

(Thinopyrum ponticum)

A robust perennial grass for sustainable biomass production



Description of the crop

Botanical identity, main characteristics and key traits



Origin and cultivation area

Native range and current distribution in Europe and worldwide



Soil and climate preferences

Optimal growing conditions and tolerance to abiotic stresses



Cultivation protocol

Establishment methods, management and inputs



Harvesting

Timing, methods and expected yields



Uses

Bioenergy, bio-based products, forage and environmental benefits

Tall wheatgrass (*Agropyron elongatum*) – Crop description



Mature tall wheatgrass stand
(*Agropyron elongatum*)



Root system



Leaves and stems



Inflorescence (spike)



Botanical identity

Perennial, cool-season C₃ grass in the Poaceae family. Commonly referred to as *Agropyron elongatum*, and also known as *Thinopyrum ponticum* or *Elytrigia elongata* in the literature.



Growth habit and size

Robust, long-lived, sod-forming to bunchgrass habit, usually 1~2 m tall, but can be taller (up to ~2.5 m) under favorable conditions.



Root system

Deep, extensive root system with many lateral roots, contributing to high tolerance of drought, salinity and alkaline conditions.



Leaves and stems

Coarse, blue-green to grey-green leaves; upright, robust culms with grass-like morphology typical of wheatgrasses.



Inflorescence

Dense, wheat-like terminal spike composed of several spikelets arranged along the rachis.



Adaptation and key traits

Highly tolerant of salinity and alkalinity; adapted to drought and periodic water stress; performs well on marginal and degraded soils.

Key features



Persistent: long-lived perennial grass, useful for long-term stands.



Stress tolerant: high tolerance to salinity, alkalinity, drought and periodic water stress.

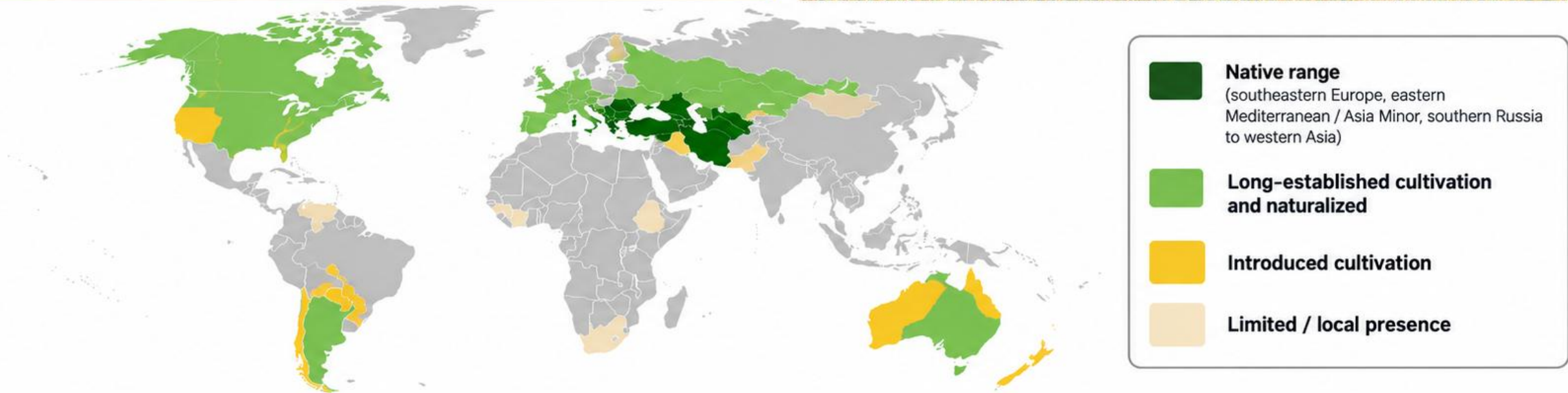


Forage and biomass: valuable for forage production and biomass on marginal soils.

Tall wheatgrass (*Agropyron elongatum*) – Origin and cultivation area

Origin

- Native to **southeastern Europe**, the **eastern Mediterranean / Asia Minor**, and **southern Russia to western Asia**.
- Often described as originating in **southern Europe** and **western Asia**.
- Well adapted to **saline, alkaline, dry and marginal lands**.



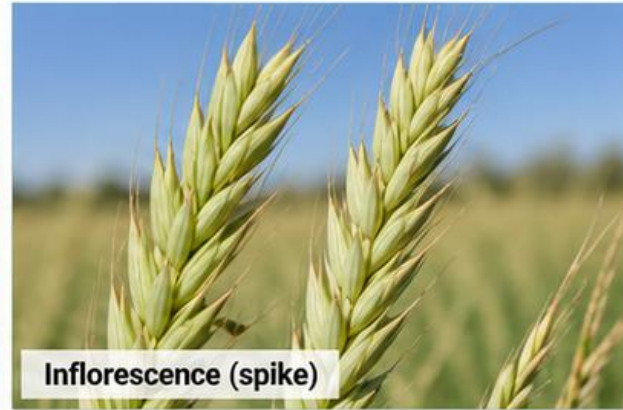
Main cultivation regions / examples

- **Mediterranean region** and **southeastern Europe** (e.g., Balkans).
- **Turkey / Near East** and **Central Asia**.
- **North America** (USA and Canada).
- **South America** (especially **Argentina**).
- **Australia**.
- Used for **forage production, pasture improvement, soil reclamation and biomass**, especially on saline, alkaline, dry or marginal lands.

Tall wheatgrass (*Agropyron elongatum*) – Soil, climate preferences and cultivation protocol



Mature tall wheatgrass stand
(*Agropyron elongatum*)



Inflorescence (spike)



Leaves and stems



Soil preferences



Adapted to marginal, low-fertility soils and performs well on sandy to loamy soils.



Highly tolerant of salinity and alkalinity; suitable for saline and alkaline lands.



Best establishment on well-drained soils; deep root system helps exploit subsoil moisture.



Useful for degraded land rehabilitation and biomass or forage production on problem soils.



Climate preferences



Perennial cool-season C₃ grass adapted to temperate, Mediterranean and semi-arid environments.



Strong tolerance to drought, periodic water stress and winter cold/frost.



Good performance in dry environments where salinity and alkalinity limit other crops.



Main vegetative growth occurs in spring and early summer.



Cultivation protocol

1



Site preparation

Prepare a fine, weed-free seedbed; basic tillage before sowing.

2



Sowing

Autumn or early spring; sow by seed at about 20–30 kg/ha, 1–2 cm depth, in rows about 15–20 cm apart.

3



Fertilisation

Moderate nutrient inputs; nitrogen can improve biomass yield depending on soil fertility.

4



Establishment care

Control weeds carefully in the first year; irrigation may help establishment in very dry areas.

5



Management

Low-input perennial stand; productive for several years once established.

6



Use/harvest note

Biomass cutting or forage use usually starts from the second year onward.



Key agronomic message



Excellent option for saline, alkaline and drought-prone lands.



Low-input perennial grass for forage and biomass.



Strong persistence once established.

Tall wheatgrass (*Agropyron elongatum*) – Harvesting



Main harvesting practices

- Harvest established stands from the 2nd year onward.
- For biomass/seed production, harvest once per year at full maturity, usually in late summer.
- Typical harvest uses mowing / swathing and baling, or direct combine/field-harvester collection for biomass and seed.
- Maintain a stubble height of about 7–10 cm to support regrowth.
- Dry biomass before baling/storage when possible to improve conservation.



What can be harvested?

- Biomass for energy or fibre uses.
- Seed from mature stands.
- Forage may also be cut earlier at vegetative to early heading stages for better feed quality.



Practical notes

- Harvest timing depends on the target product (forage vs. biomass vs. seed).
- Mature stands can remain productive for several years.
- Avoid excessive harvest delays that increase lodging and quality losses.



Mature stand ready for harvest



Cut and swathed biomass



Baled dry biomass



Key message



One harvest at maturity



Low-input perennial stand



Biomass, seed or forage use

Tall wheatgrass (*Agropyron elongatum*) – Uses



Forage use



Biomass / energy use



Baled raw material



Main uses

- Forage and hay, especially for saline or marginal lands.
- Biomass for solid biofuel, combustion and other energy uses.
- Feedstock for biogas or second-generation biofuels.
- Raw material for fibre, pulp, paperboard and lignocellulosic products.
- Useful in land rehabilitation and soil protection on problem soils.



Why it is valuable

- Productive perennial grass with relatively low input needs.
- Performs where salinity, alkalinity or drought limit conventional crops.
- Can supply biomass, forage and seed from the same production system.
- Deep root system contributes to persistence and soil cover.



Example application pathways



Forage / pasture



Bioenergy



Fibre / paper materials



Reclamation / erosion control



Key message



Forage on marginal land



Biomass for energy and fibre



Multi-purpose perennial crop

Reed canary grass

(*Phalaris arundinacea* L.)

Contents

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Crop description

2



Origin of the crop

3



Soil and climate preferences

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Cultural protocol

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Harvesting

6



Uses



Reed canary grass (*Phalaris arundinacea* L.) – Crop description



Botanical identity

Perennial, rhizomatous grass belonging to the family Poaceae.



Growth habit and size

Erect culms commonly 0.6–2.0 m high, sometimes up to ~ 2.2 m.



Rhizomes

Strong, creeping and scaly rhizomes, forming dense stands.



Leaves

Broad, flat leaves, typically 5–25 mm wide.



Inflorescence

Contracted to narrow panicle, about 5–30(40) cm long; green to purplish when young, becoming straw-coloured at maturity.



Reproduction

Reproduces by rhizomes (vegetative shoots) and by seed.



Pollination

Cross-pollinated and wind-pollinated.



Natural habitat

Naturally associated with moist meadows, ditches, stream and lake margins and other wet habitats.



Stand development

Can form extensive, dense stands due to vigorous rhizomatous growth.



Full plant in the field



Panicle (inflorescence)



Stems, leaves and rhizomatous base

Reed canary grass (*Phalaris arundinacea* L.) – Origin & cultivation area



Native origin & range

- Native to temperate and subtropical regions of the Northern Hemisphere, including Europe, Asia and parts of North America.
- Extends into some tropical mountain regions.
- In North America, the history is complex: native lineages occur, but European germplasm/cultivars were also introduced and contributed to expansion.



European cultivation

- Widely cultivated as a forage crop and, in northern and central Europe, evaluated and grown as a perennial lignocellulosic biomass/energy crop.
- Main examples: Finland, Sweden, the Baltic region, Poland, the UK and other cool-temperate European areas.



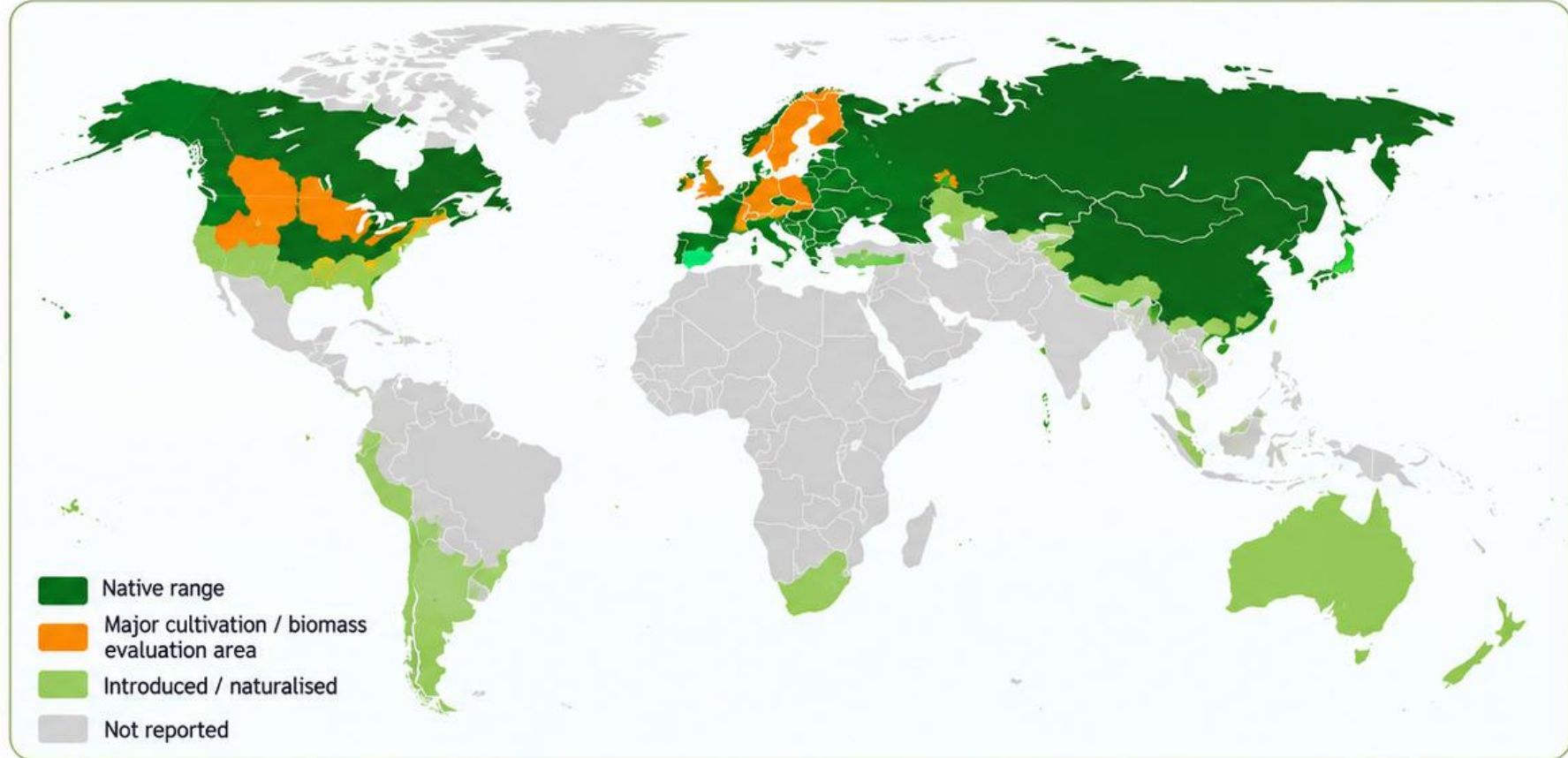
North American use

- Cultivated and managed for forage, conservation (e.g. erosion control, wetland restoration) and biomass applications.
- Both native and introduced (mainly European) genotypes are present.



Natural habitats

- Moist meadows, riverbanks, ditches, lakeshores, floodplains and other wet or open habitats.



Reed canary grass (*Phalaris arundinacea* L.) – Soil & climate preferences and cultivation protocol



Soil preferences

- Performs best on **moist to wet soils**, including alluvial, peaty, silty or fertile loamy soils.
- Tolerates periodic **waterlogging** and **poor drainage** better than many forage grasses.
- Can also be cultivated on **lighter/sandy soils** under temperate conditions, but productivity benefits from fertilisation.
- Adapted to a **wide pH range**, roughly from slightly acidic to neutral/alkaline conditions.
- Shows **tolerance to marginal conditions**; some genotypes display tolerance to salinity.



Climate preferences

- Cool-season perennial C3 grass adapted to **temperate and boreal climates**.
- High **winter hardiness** and strong regrowth from rhizomes.
- Prefers areas with **adequate moisture** and **cool to moderate temperatures**.
- Performs well in regions with **cold winters and moderate rainfall**; drought can reduce productivity.
- Suitable for **moist habitats** such as meadows, ditch margins and flood-prone areas.

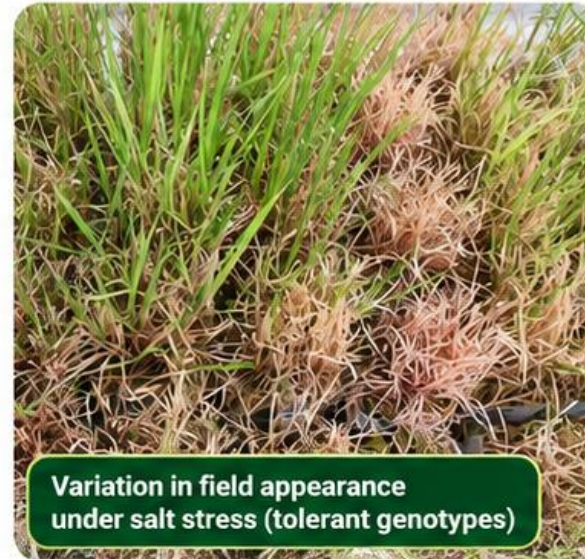


Cultivation protocol

- Establish from seed in **spring** on a fine, firm seedbed.
- Shallow sowing (about **1–2 cm**) because seeds are small.
- Typical row spacing can be narrow to moderate; ensure **good seed-soil contact**.
- **Weed control** is critical during the establishment year.
- **Moderate nutrient inputs** are usually sufficient; compost and N fertilisation can increase biomass yield.
- As a perennial crop, **tillage** is mainly needed only at establishment.
- For energy biomass, **harvest at full maturity or after overwintering**, depending on the target end use.



Dense reed canary grass stand at flowering



Variation in field appearance under salt stress (tolerant genotypes)



Reed canary grass in a temperate landscape

Reed canary grass (*Phalaris arundinacea* L.) – Harvesting



When to harvest

- Harvest biomass from established stands, usually from the **second year onward**.



Timing for energy biomass

- Commonly harvested **once per year** at **full maturity** in **late autumn, winter or early spring** after senescence/overwintering.



Benefits of delayed harvest

- Delayed harvest **lowers biomass moisture** and **reduces ash and mineral contents**, improving fuel quality.
- Some dry matter yield may be lost compared with earlier harvest.



Typical harvest operations

- **Mowing or swath**ing, followed by **field drying** when needed, then **baling or chopping** and collection.



Biomass handling and storage

- Biomass can be stored as **round or square bales** or handled as **chopped material**.



Dual-purpose systems

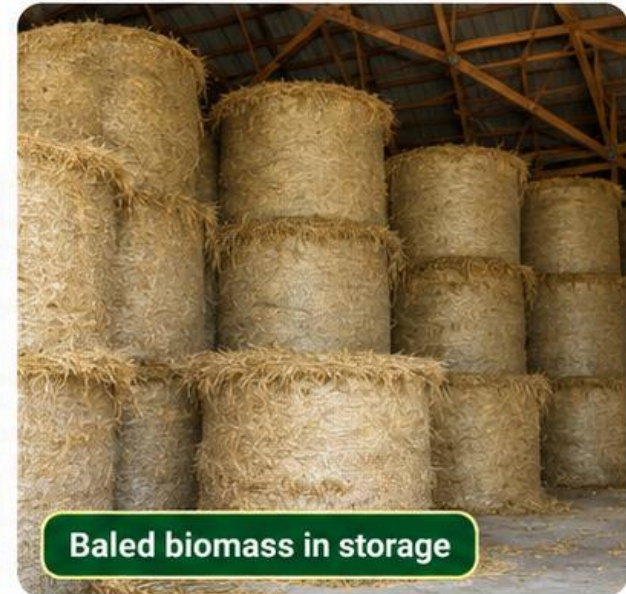
- In some systems, **seed may also be harvested** in early years, but the main harvest for bioenergy is the above-ground biomass.



Mature stand at harvest



Cutting / windrowing



Baled biomass in storage

Reed canary grass (*Phalaris arundinacea* L.) – Uses



Solid bioenergy

- Combustion as **baled or chipped biomass**
- Pellets, briquettes and **co-firing applications**



Biofuels

- Feedstock for **biogas** and **cellulosic ethanol**
- Lignocellulosic biomass for **renewable energy chains**



Bio-based materials

- Fibre for **pulp, paper** and other biomaterials
- Potential use in **fibreboards** and **insulation products**



Farm uses

- Young biomass can be used as **forage**
- Dry mature biomass can be used as **animal bedding**



Environmental uses

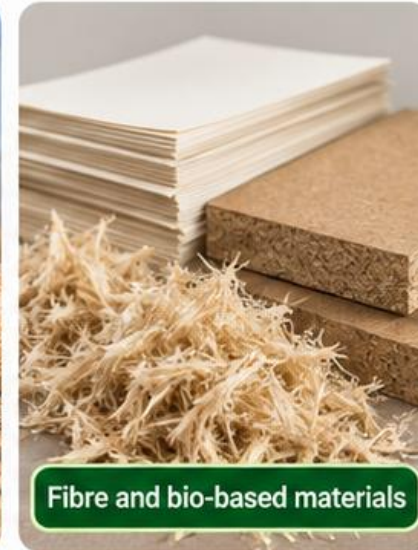
- Buffer strips, **phytoremediation** and nutrient capture
- Habitat support and biomass production on **marginal land**



Baled biomass for energy use



Solid bioenergy products



Fibre and bio-based materials



Environmental applications



Cardoon (*Cynara cardunculus* L.)

Contents

1



Crop description

2



Origin of the crop

3



Soil and climate preferences

4



Cultural protocol

5



Harvesting

6

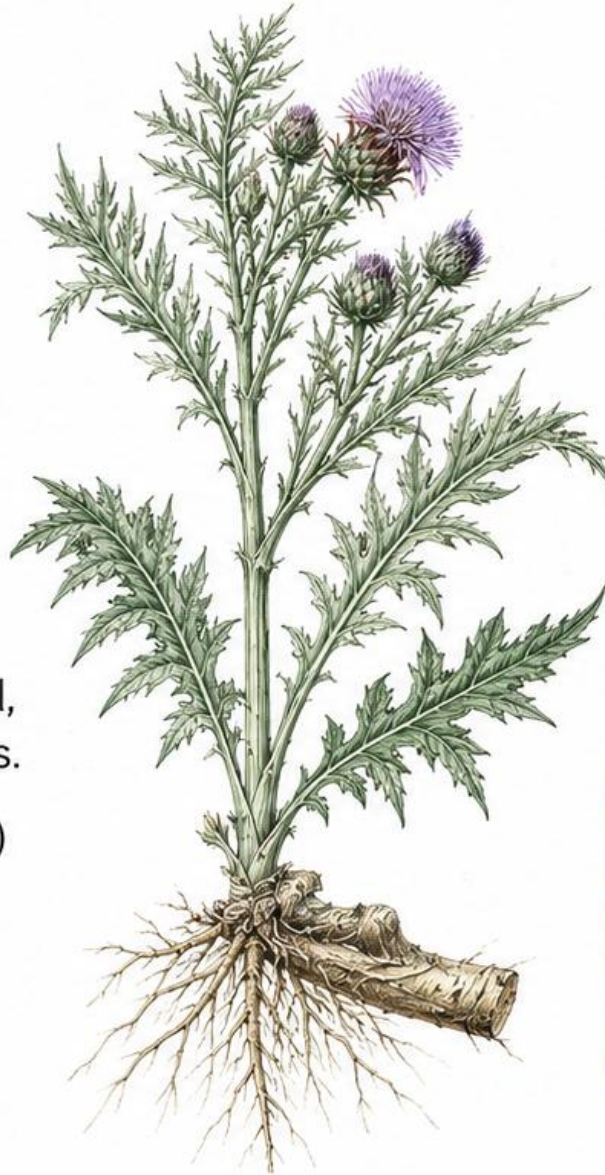


Uses



Cardoon (*Cynara cardunculus* L.) – Crop description

- **Perennial herbaceous thistle** of the **Asteraceae** family; cultivated cardoon corresponds to *C. cardunculus* var. *altilis*.
- Robust **perennial root system** with a deep taproot and crown; above-ground growth follows an annual cycle and regrows after summer dormancy.
- Basal rosette of **large grey-green, deeply lobed leaves**; leaves are often spiny, although spineless types also exist.
- **Erect, branched stems** usually 1.5–2.5 m tall, occasionally taller under favourable conditions.
- Violet to blue-purple **flower heads** (capitula) produced in spring–early summer; cross-pollinated species.
- Fruits are **achenes with pappus**; seedlings establish first, then rosette, stem elongation, flowering and seed maturity.



Flower head



Mature head / pappus



Seeds



Seedling



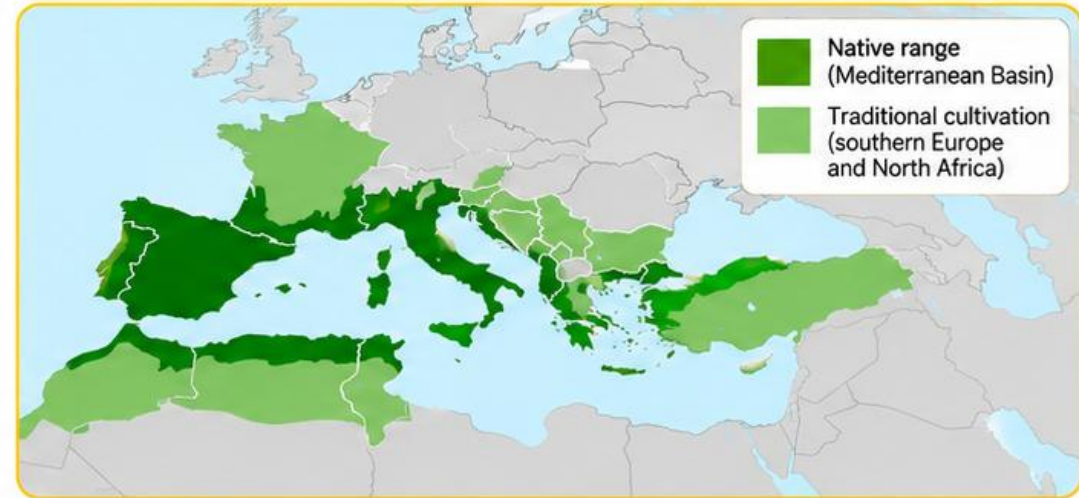
Young rosette

Cardoon (*Cynara cardunculus* L.) – Origin & cultivation area

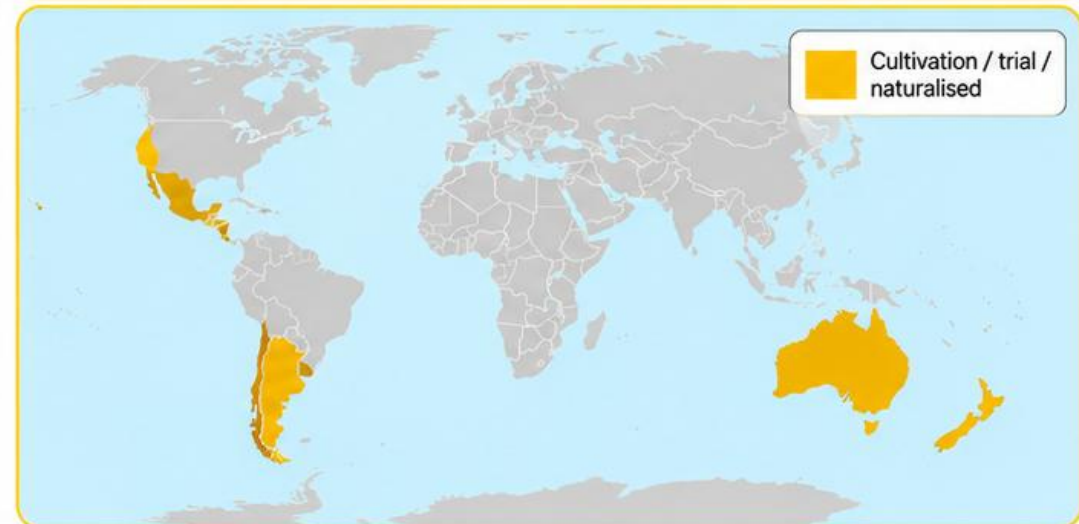
- **Native** to the **Mediterranean Basin**.
- Cultivated cardoon derives from wild cardoon and was **domesticated in the western Mediterranean**.
- **Traditionally cultivated** in **southern Europe** and **North Africa**, especially **Spain, Portugal, Italy, France, Greece, Morocco, Algeria and Tunisia**.
- Today it is also grown, trialed, or naturalised in **other regions with Mediterranean-type climates**, including the USA (especially California), Mexico, Chile/Argentina, Australia and New Zealand.
- It is best adapted to **dry Mediterranean environments** and is widely studied as a **biomass crop** in southern Europe.



Native and traditional cultivation area (Mediterranean region)



Other cultivation, trial or naturalisation areas (global)



Cardoon (*Cynara cardunculus* L.) – Soil & climate preferences



Soil preferences

- Best on **deep, well-drained soils**.
- Performs well on **poor, marginal, stony or low-fertility** Mediterranean soils.
- Tolerates **moderate drought and some salinity** better than many annual crops.
- **Avoid prolonged waterlogging** and very compacted soils.
- Usually performs well from **neutral to moderately alkaline** conditions.



Climate preferences

- Well adapted to **Mediterranean climates** with mild, wet winters and hot, dry summers.
- **Autumn establishment** is favored where winter rainfall supports vegetative growth.
- **Drought tolerant** once established because of its deep root system.
- Biomass production is generally higher under sites with **adequate winter–spring rainfall**.
- **Sensitive mainly during establishment**; mature stands are resilient in semi-arid conditions.



Cultivation notes

- Usually established by **direct seeding in autumn**; spring sowing is possible in cooler areas.
- **Weed control** is important during the first year of establishment.
- Generally grown as a **low-input perennial crop**, often with little or no irrigation.
- **Moderate fertilization** can be used, but the crop is suitable for marginal land systems.
- Productive stands can **persist for several years** after establishment.

Established stand



Plantation development over subsequent years



Year 1 – Establishment
(2nd year)



Year 2 – Developing stand
(3rd year)



Year 3 – Mature stand
(4th year)



Vegetative stage



Flowering stage

Cardoon (*Cynara cardunculus* L.) – Harvesting

- Productive stands are usually **harvested from the 2nd year onward**, after the establishment year.
- Harvest is generally carried out in **late summer to early autumn**, when the crop is dry and stems and heads are fully mature.
- Delayed harvest helps **reduce biomass moisture and ash problems**, improving storage and suitability for energy use.
- Two main harvest options are used: (a) **whole above-ground biomass** for lignocellulosic use, or (b) **separate seed harvest** followed by biomass collection.
- Conventional machinery can be used, including **combine harvesters** for heads/seeds and **forage or biomass harvesting systems** for the remaining dry biomass.
- Under low-input Mediterranean systems, **one harvest per year** is the usual practice.



Examples of mechanical harvesting of cardoon biomass and heads.

Cardoon (*Cynara cardunculus* L.) – Main uses



Bioenergy & biofuels



- Solid biomass for combustion, pellets or briquettes
- Anaerobic digestion for biogas / biomethane
- Lignocellulosic feedstock for bioethanol
- Seed oil suitable for biodiesel



Food, feed & seed products



- Traditional vegetable use of leaf stalks
- Protein-rich seed cake / residues for feed
- Seeds as a source of oil and valuable compounds



Biobased materials



- Pulp and paper
- Natural fibres and biocomposites
- Insulation and fibre-based materials



Biorefinery & high-value compounds



- Cellulose and hemicellulose fractions
- Inulin from roots
- Phenolics and other phytochemicals

Wild sugarcane (*Saccharum spontaneum* L.)

Contents

-  **1** | Crop description
-  **2** | Origin of the crop
-  **3** | Soil and climate preferences
-  **4** | Cultural protocol
-  **5** | Harvesting
-  **6** | Uses



Wild sugarcane (*Saccharum spontaneum* L.)



Inflorescence
(silvery panicle)

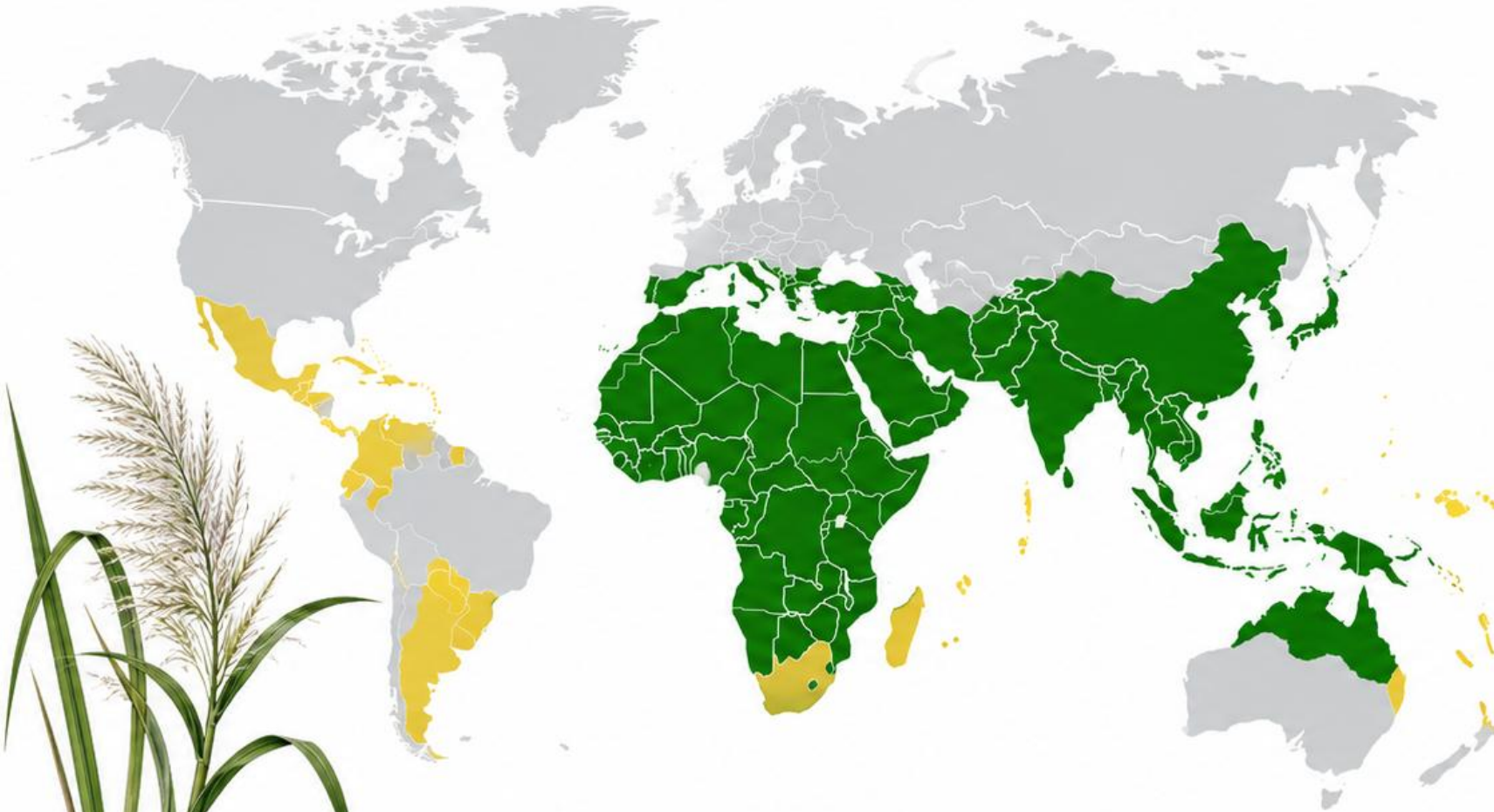


Culms (cane-like stems)

Crop description

- **Perennial rhizomatous grass** in the Poaceae family.
- **Tall, vigorous clumps**, typically about 2–4 m high or more.
- **Cane-like culms** with many tillers.
- **Long, narrow leaves** with sharp margins.
- **Large, loose, silky white to silvery panicles** (inflorescences).
- **Extensive rhizome system** that helps rapid spread and regrowth.
- **Adapted to riverbanks, floodplains** and disturbed sites.
- **Important wild relative and genetic resource for sugarcane breeding** because of its vigor and tolerance to environmental stresses (e.g. drought, flooding, salinity).

Origin and cultivation area of Wild sugarcane (*Saccharum spontaneum* L.)



Wild sugarcane
(*Saccharum spontaneum* L.)

- Native range** (Mediterranean, Africa, Middle East, Asia to N & NE Australia)
- Introduced** (in some other tropical and subtropical regions)



Native origin and range

Native to the Mediterranean region (including Sicily), large parts of Africa, the Middle East, South Asia, East and Southeast Asia, and extending to northern and northeastern Australia and New Guinea.



Habitat and climate

Common in warm tropical to subtropical regions, especially along riverbanks, floodplains and other alluvial plains.



Widespread distribution

Particularly widespread in the Indian subcontinent and Southeast Asia.



Status and importance

Mainly present as a wild or managed naturalized species, and also valued as an important genetic resource for sugarcane improvement.

Wild sugarcane (*Saccharum spontaneum* L.) – Soil and climate preferences & cultural practices



Soil and climate preferences

- **Warm tropical to subtropical climates**; also adapted to warm-temperate Mediterranean conditions.
- Prefers **full sun** and a long warm growing season.
- Grows best on **moist, fertile alluvial soils**, but also adapts to sandy, silty and marginal soils.
- Tolerates **periodic flooding or waterlogging**, and shows good tolerance to **drought and salinity**.
- Common along **riverbanks, floodplains, coastal zones** and other disturbed sites.



Cultural practices

- Usually established vegetatively by **rhizome pieces or stem cuttings** with viable nodes.
- Plant at the **beginning of the warm or rainy season** in a well-prepared, weed-free seedbed.
- Use **adequate spacing** to allow clump expansion and easy stand management.
- Provide **irrigation** mainly during establishment in dry areas; mature stands are more resilient.
- Apply **light to moderate fertilisation** according to soil fertility; **weed control** is most important during establishment.
- Perennial stands **regrow from rhizomes** and can persist for many years.



Field stand



Silky panicles (close-up)



Flowering stand

Wild sugarcane (*Saccharum spontaneum* L.) – Harvesting

Main harvesting practices

- 1 Harvest at the **end of the growing season or dry season**, when stems are mature and biomass moisture is lower.
- 2 Cut stems **close to the ground**, while preserving rhizomes for regrowth.
- 3 Harvesting can be **manual** with sickles/ machetes or **mechanical** using forage/ sugarcane harvesters.
- 4 Biomass can be **chopped during harvest** or cut and collected for transport.
- 5 Keep harvested biomass as **clean as possible** and remove excess impurities (soil, stones, weeds, etc.).
- 6 Established stands **regrow from underground rhizomes** after harvest.



Mechanical harvest



Loading chopped biomass



Harvested stand / transport

Wild sugarcane (*Saccharum spontaneum* L.) – Uses



Wild sugarcane biomass

Main uses

- 1 Bioenergy & biofuels:** lignocellulosic biomass for direct combustion, pellets/briquettes, cellulosic ethanol and other bioenergy pathways.
- 2 Fibre & bio-based materials:** potential feedstock for pulp/paper, particleboards, insulation and other fibre-based materials.
- 3 Traditional rural uses:** stems and leaves used locally for thatching, mats, ropes, fencing and similar household applications.
- 4 Environmental uses:** useful for riverbank stabilisation, erosion control, land rehabilitation and phytoremediation on marginal or disturbed sites.
- 5 Breeding & ethnobotanical value:** important genetic resource for sugarcane improvement, with reported traditional medicinal uses in some regions.

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MARGINAL LANDS, INDUSTRIAL CROPS
AND INNOVATIVE BIO-BASED VALUE CHAINS

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Thank you



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Funded by
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This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101082070. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or REA. Neither the European Union nor the granting authority can be held responsible for them.