Growing sugar crops in EU

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World sugar balance

Sugar production & consumption:

	2008/09 (Mt)	2009/10 (Mt)
Production	152.9	153.3
Consumption	164.3	167.1
Deficit	-11.4	-13.8

(Source: International Sugar Organization (ISO, Nov. 2009))

World sugar balance

Main producers:

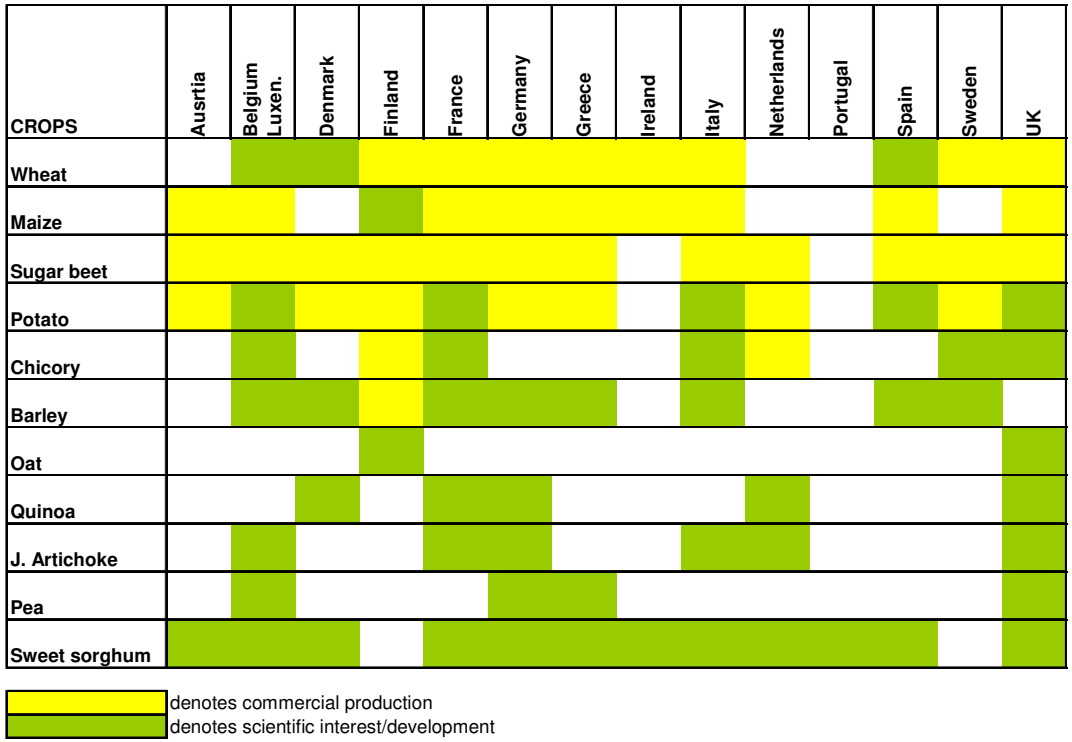
Countries	Sugar prod. (Mt)	% world production	Down/up from 2008/09
Brazil	35.8	23	Down
India	17.3	11	Down
EU-27	15.4	10	Up
China	13.2	9	Down
Thailand	7.7	5	Up
Australia	3.7	2	Up
Others	60.2	39	Up

(Source: ISO)

Sugar crops

Main sugar crops:

- Barley
- Breadfruit
- Blue Agave
- Cassava (yuca, manioc)
- Jerusalem artichoke
- Potato
- Maize
- Oats
- Pea
- Quinoa
- Root chicory
- Sugar beet
- Sugar cane
- Sweet potato (batata, yam)
- Chinise yam (Igname, Dioscorea b.)
- Wild taro (Colocasia antiquorum)
- Sweet sorghum
- Wheat



Root chicory (*Chicorium intybus*)

It became famous as coffee substitute in **1806** when Napoleon eliminated the British coffee imports**,** and again during the **"coffee crisis" (1976-79)** when the price of imported coffee quadrupled (used in the German "Mischkaffee", mixed coffee);

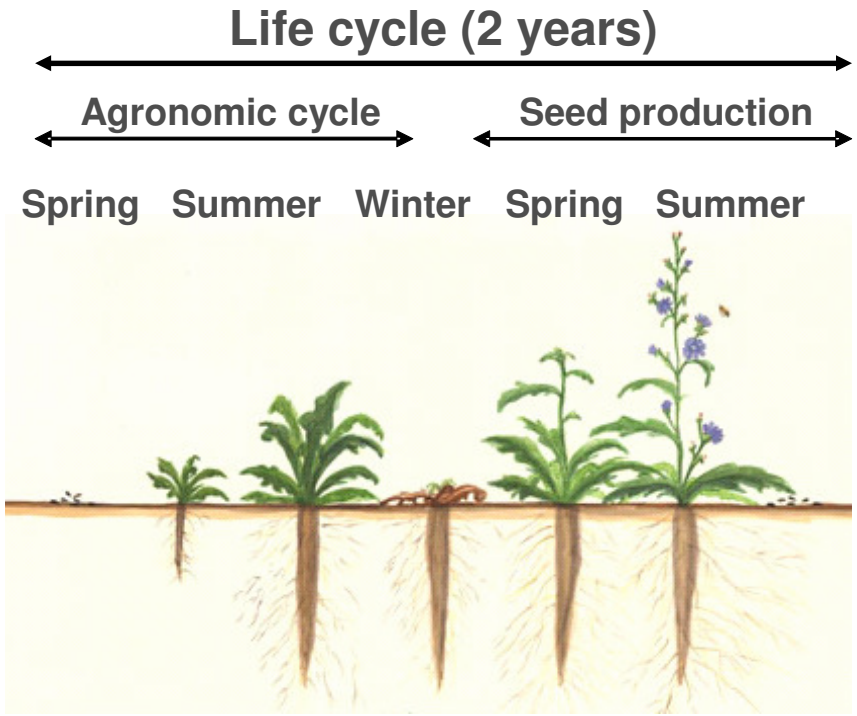
Today, of 36.000 fructan-containing species, only 3 are practically cultivated for inulin: **chicory**, **Jerusalem artichoke**, and **blue agave,** the last for the tequila.

In Europe, **root chicory** is mostly grown in Central-Northern countries (BE, NL and FR), however there is evidence that it could be successfully cultivated also in South Europe.

Growing root chicory

SHORT DESCRIPTION

- Family: *Compositae*; Genus: *Chicorium*
- C3 biennial crop native to Russia.
- **Deep taproot** up to 75 cm long which is the marketable organ.
- Leaves could be used as feed.
- Numerous flower-heads. Fruit is an achene 2-3 mm long.



ECOLOGY

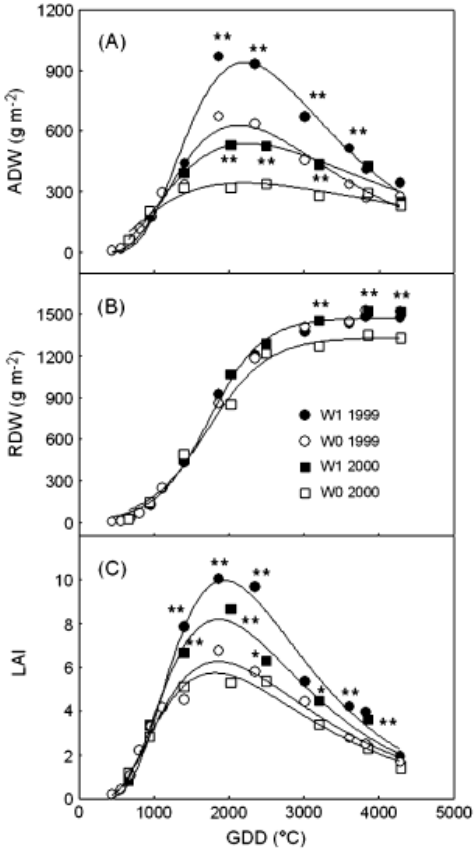
- Practically any type of soil, but better on deeply tilled sandy soils.
- It weakly tolerates high summer temperatures needing irrigation under durable stress.
- It tolerates pH from 4.5 to 8.3.

Growing root chicory

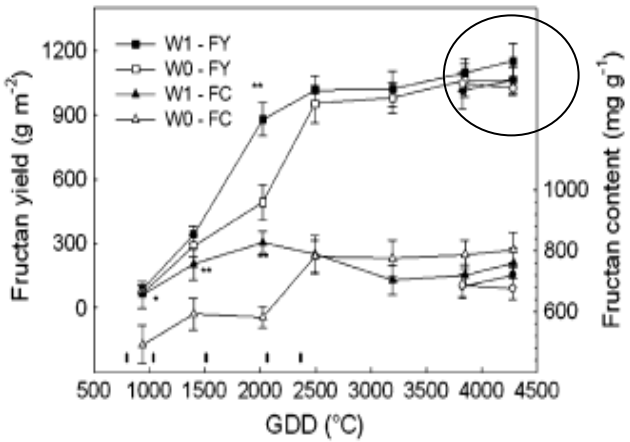
Cultivation practice is very similar to that of sugar beet

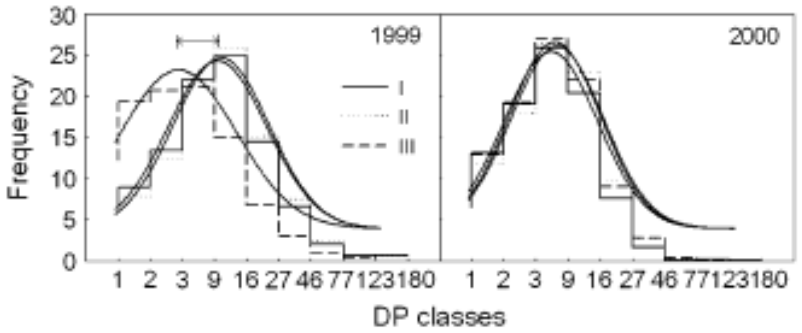
- **Ploughing:** about 30 cm depth. Due to a very small seed size, you need a firm seed bed at seeding time;
- **Seeding:** as soon as possible (late February-March) but attention to pre-flowering (use genotypes resistant to that!);
- **Plant density:** 13-15 plants m^{-2}, 45-60 cm row spaced;
- **Fertilization:** 60-80 kg/ha (N); 80-100 kg/ha of P_2O_5 & K_2O;
- **Harvesting:** in Autumn as root weight increases significantly during cool weather.

Irrigation effect in North Italy



Growing root chicory





(Monti et al., 2005. J. Exp. Bot.)

At final harvest, fructan yield did not vary between irrigated and not irrigated plants in North Italy.

Delaying harvest may lead to a lower fructan quality (< DP under low temperatures).

Jerusalem artichoke (*Helianthus tuberosus*)

SHORT DESCRIPTION

- Family: *Compositae*; genus: *Helianthus*. Also known as **topinambur.**
- C3 perennial crop native to the East U.S.;
- Up to 4 m tall;
- Tubers knobby, white, red or purple skinned, ranging from 7 – 10 cm long, vaguely resembling ginger roots.

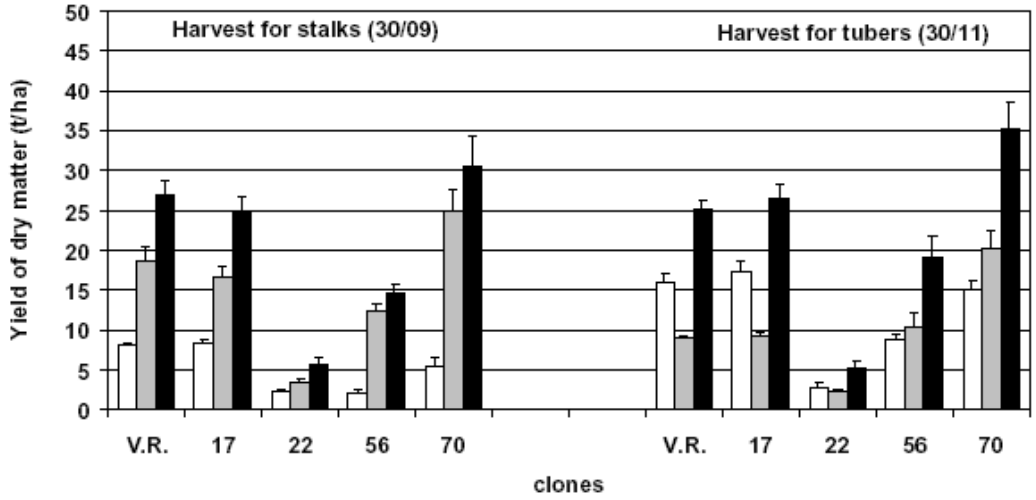
ECOLOGY

•Tolerant to wind and cold.
•Light and well-drained sandy loam soils are more suitable.
•It tolerates hot to sub-zero temperatures.
•Tubers are frost hardy.

Growing Jerusalem artichoke

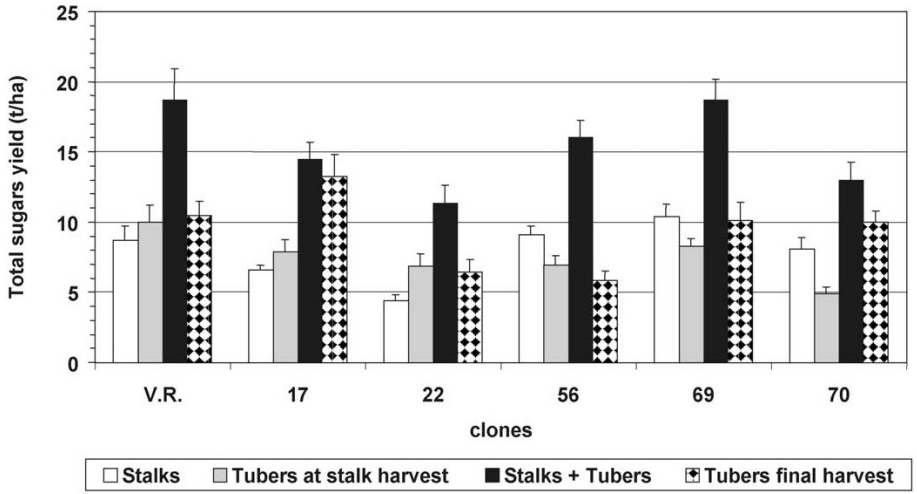
- **Propagation:** by tubers (pieces about 50 g covered to a depth of 10 cm).
- **Plant density:** 2-4 plants m^{-2} in rows 0.7-1 m apart;
- **Fertilization:** 60-80 kg ha^{-1} N and P, 150 kg ha^{-1} of K;
- **Weed control**: non-chemical weed control is available
- **Harvesting**: Late summer harvest for stems only (before inulin translocation); Autumn harvest for stems (combustion?) and tubers (inulin), or tubers only.
- **Problems**: can act as a weed for the following crops (impossible to remove all tubers at harvest). Attacked by several fungi and bacteria.

Growing Jerusalem artichoke



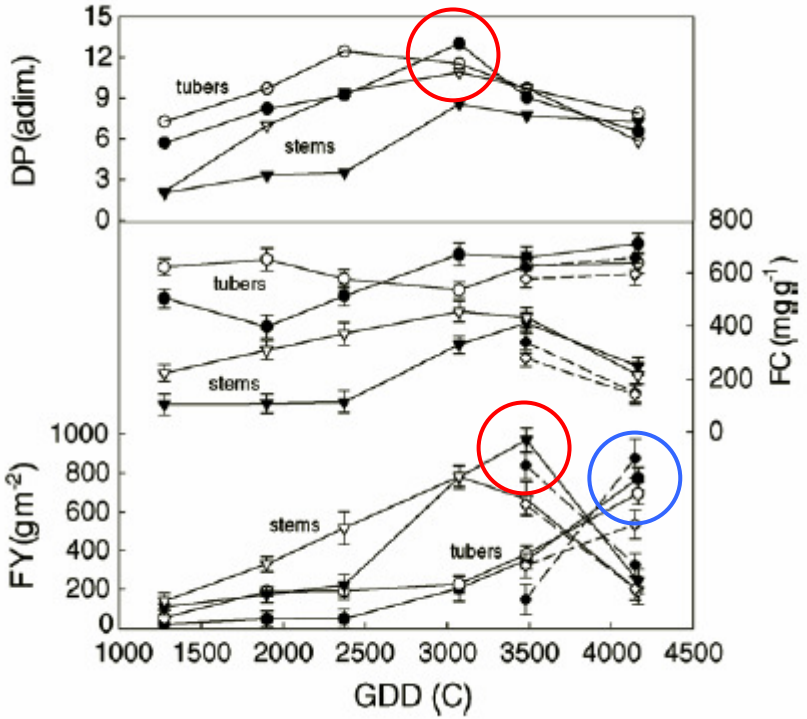
Dry biomass production on summer and autumn harvests (different clones)

Sugar (inulin) production on summer and autumn harvests



(Baldini et al., Eur. J. Agron.)

Growing Jerusalem artichoke



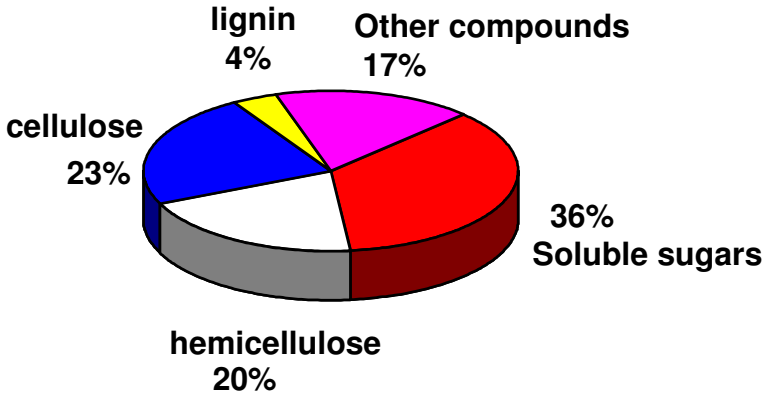
(Monti et al., Field Crops Res.)

Fructan yield (FY) and degree of polymerization (DP)

Sweet sorghum (*Sorghum bicolor* spp. *bicolor* Moench)

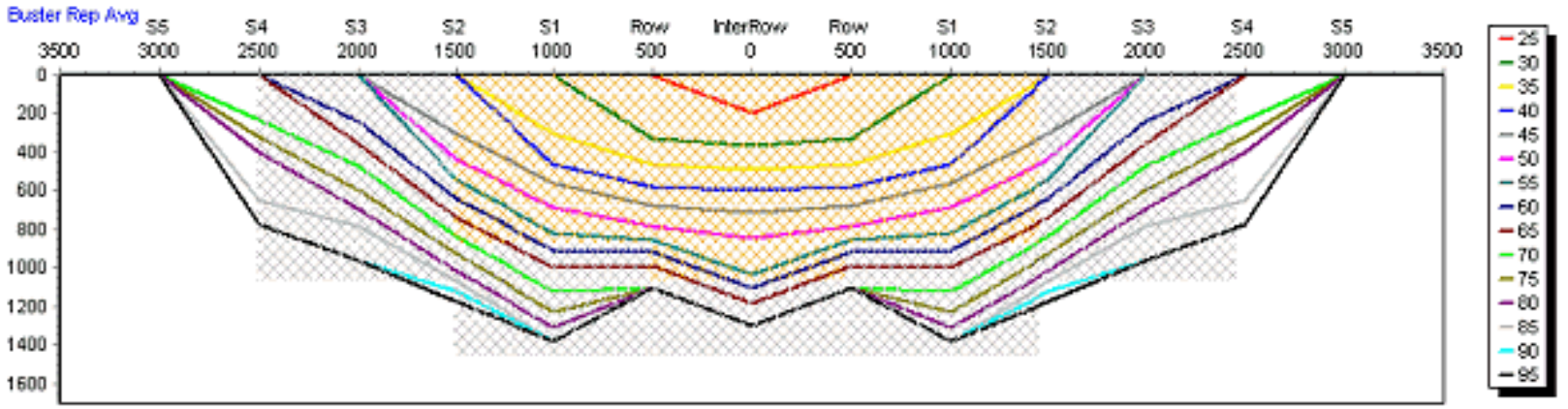
SHORT DESCRIPTION

- Family: Poaceae; Genus: Sorghum.
- Sweet sorghum is similar to grain sorghum but much taller and with sugar-rich stalks.
- C4 annual plant, similar to maize but taller (up to 5 m) and more vigorous (up to 50 g m^{-2} d^{-1}).
- Stout culms is terminated by inflorescence (panicula). It contains a juice with soluble sugars from 15 to 40% (d.w. basis).
- The minimum growth temperature is high (about 14-16 °C).



Sweet sorghum

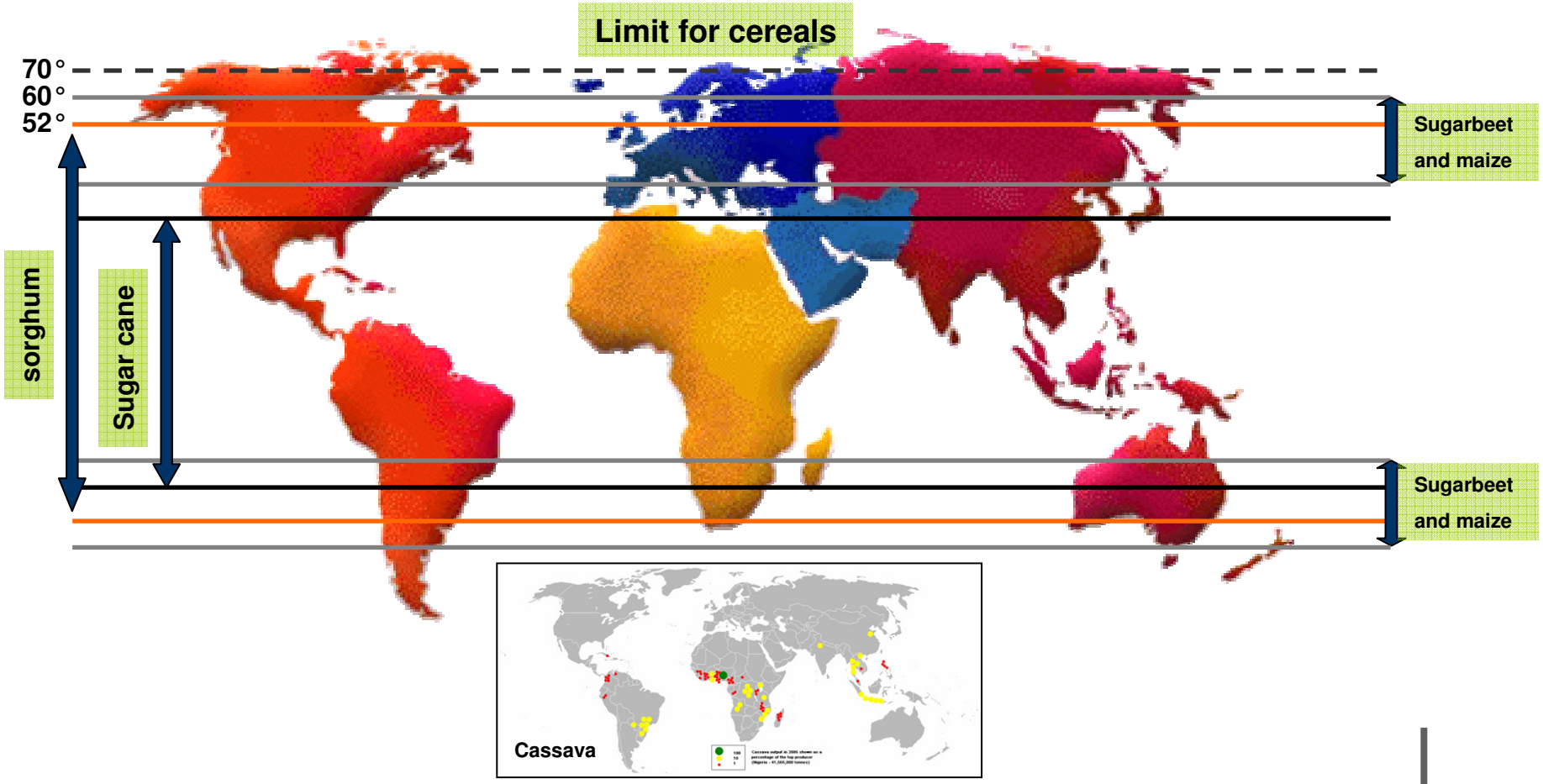
Compared to maize, sorghum has thinner and more expanded roots that enable it to uptake about double water than maize under stress conditions



Limit of water extraction every 5 days (25-95). The colored lines indicate the extent of water extraction measured at the associated days after sowing (Broad and Hammer, Crop Sci 2006)

Growing sweet sorghum

Because of the broad adaptability and a traditional non-food use, sorghum has the potential to compete with maize and sugar cane as a biofuel crop



Growing sweet sorghum

Compared to MAIZE, it has the following advantages:

- Greater resilience to abiotic stresses;
- Broader cultivation area;
- Lower input requirements (N, water etc..);
- It contains simple sugars thus eliminating the starch conversion;
- Lower cost per unit ethanol

The main barrier is likely the huge cost of big processing plants. In fact, while starch can be easily stored for long time, simple sugars are to process immediately. Moreover, maize is more familiar to farmers.

Table 1. Sweet sorghum scores over sugarcane and maize

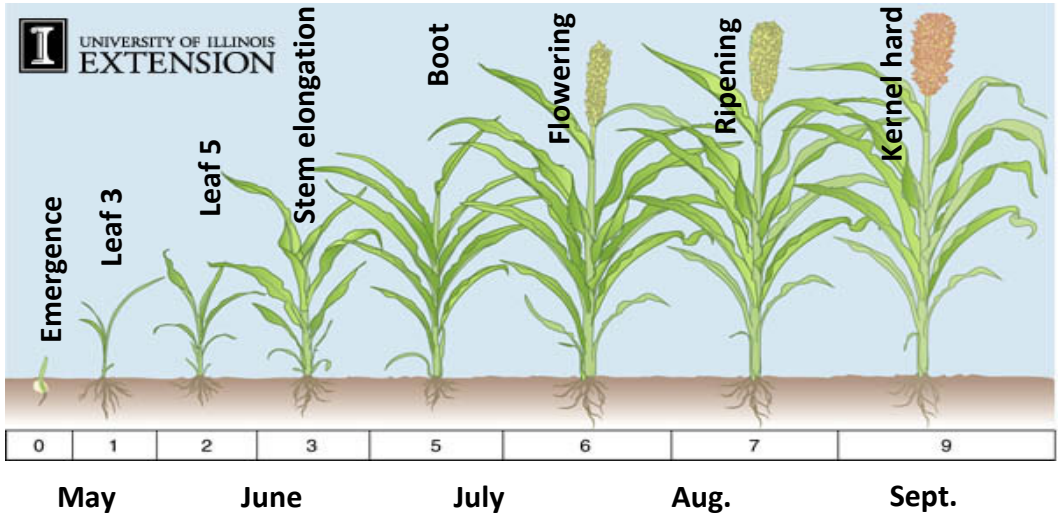
Parameter	Sweet sorghum[2]	Sugarcane[2]	Maize[3]
Crop duration	4 months	12 months	4 months
Water requirement	4000 m^3	36000 m^3	8000 m^3
Grain yield (t ha^{-1})	2.0	-	3.5
Ethanol from grain (l ha^{-1})	760	-	1400
Green stalk cane yield (t ha^{-1})	35	75	45
Ethanol from stalk cane juice (l ha^{-1})	1400	5600	0
Stillage/ stover (t ha^{-1})	4	13.3	8
Ethanol from residue (l ha^{-1})	1000	3325	1816
Total ethanol (l ha^{-1})	3160	8925	3216
Corn oil (l ha^{-1})[4]	-	-	140
Income from corn oil (US$ ha^{-1})	-	-	61
Cost of cultivation (US$ ha^{-1})	220	995	272
Cost of cultivation (ha^{-1}) after corn oil profit (US$)	220	-	211
Cost of cultivation with irrigation water cost (US$)[5]	238	995	287
Ethanol cost per kilo liter (US$)[6]	88.8	111.5	89.8
Ethanol cost per kilo liter (US$)[7]	75.3	111.5	89.2

1. Processing costs assumed equal and excluded from the estimates; does not take into account water needs and crop duration
2. Sorghum grain ethanol: 380 l t^{-1}; sorghum stalk juice ethanol: 40 l t^{-1}; sorghum or sugarcane stillage ethanol: 250 l t^{-1} [Ref. Badger (2002) Trends in New Crops and New Uses];
3. Corn (grain) ethanol: 400 l t^{-1}; maize stover ethanol: 227 l t^{-1} [Ref. Badger (2002) Trends in New Crops and New Uses];
4. Oil produced from corn: 40 l t^{-1}; oil cost of production: Rs 15 l^{-1}; oil sale price: Rs 35 l^{-1};
5. Sorghum needs two irrigations and maize four each @ the cost US$19 ha^{-1} per irrigation in rainy season
6. Without accounting for water cost; 7.After accounting for water cost

ICRISAT (2006)

Growing sweet sorghum

Early sown allows to escape drought periods in critical phases.
Identifying cold- and drought-tolerant genotypes has been the main goal of recently concluded or ongoing Projects (e.g. Sweet&Fibre Sorghum and SWEETFUEL).



(Scale by Vandelip&Reeves)

CULTIVATION

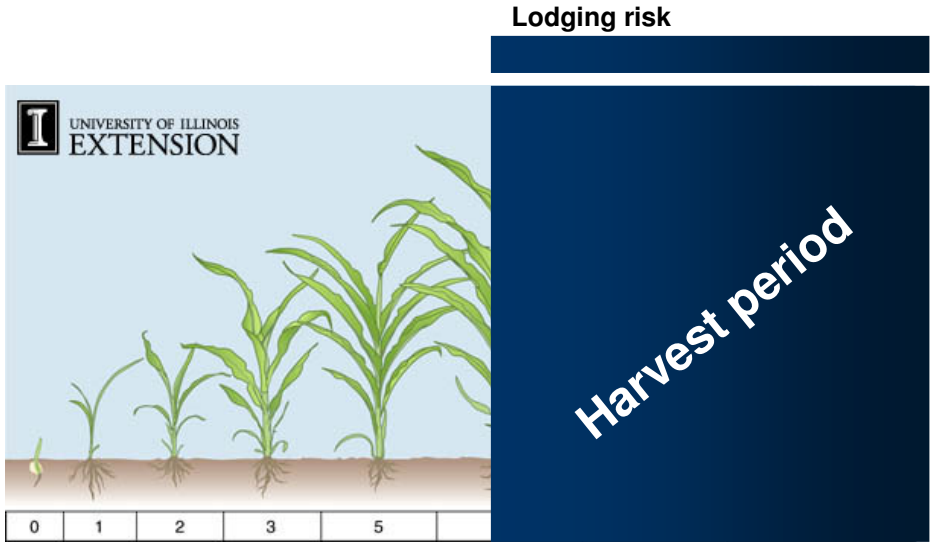
- **Soil tillage**: accurate thus to have a firm seedbed (small seed size and low early vigor);
- **Sowing**: when soil temperature is about 10-12°C. Pneumatic drill mach. (seeds 2 cm depth;
- **Plant density:** optimal 12-13 plants m^{-2}, 45 cm row spaced.
- **Fertilization**: mineral uptake (kg/t d.w.) is: 10.5 (N); 1.1 (P) and 4.6 (K). Mineral uptake is particularly intense in the first 80 days.

Growing sweet sorghum

Weed control: very important because of the low early vigor. Same products as maize.

Irrigation: Generally needed in the Mediterranean area (not in North Italy).

Harvest: different schemes: i) cutting – windrowing – baling; ii) cutting – chipping – ensiling.



Harvesting in milk stage probably maximizes the yield. Later harvest increases lodging risks because of wind, panicula weight and lower stretching structures.

Growing sweet sorghum

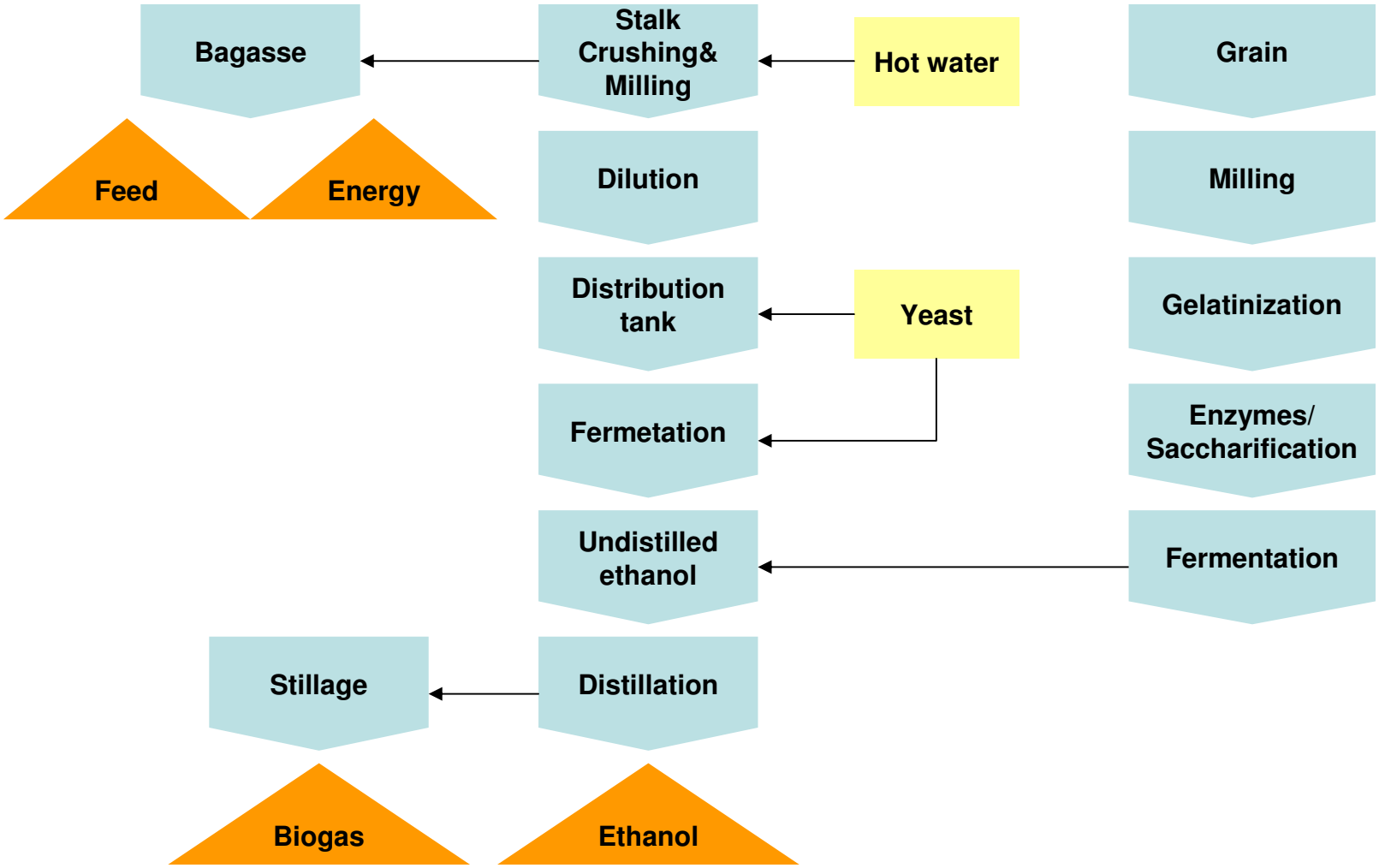
Productivity:

Table 1
Mean values for plant height, dry matter (d.m.) content, and biomass yield of the hybrids in the irrigated trials

Hybrids	Plant height (cm)	d.m. content at harvest (%)	Biomass yield (d.m.) ($Mg\,ha^{-1}$)
H132	355	30.1	27.7
H128	307	35.6	19.6
Abetone	333	30.4	23.7
ABF11	289	35.0	18.6
ABF14	298	35.7	19.1
ABF18	294	37.0	20.2
ABF20	326	33.2	23.4
ABF25	338	34.6	28.2
ABF306	294	34.4	21.3
L.S.D. ($P = 0.05$)	31.44	3.15	5.19

Large variability among genotypes

Processing sweet sorghum



Sugar beet (*Beta vulgaris*)

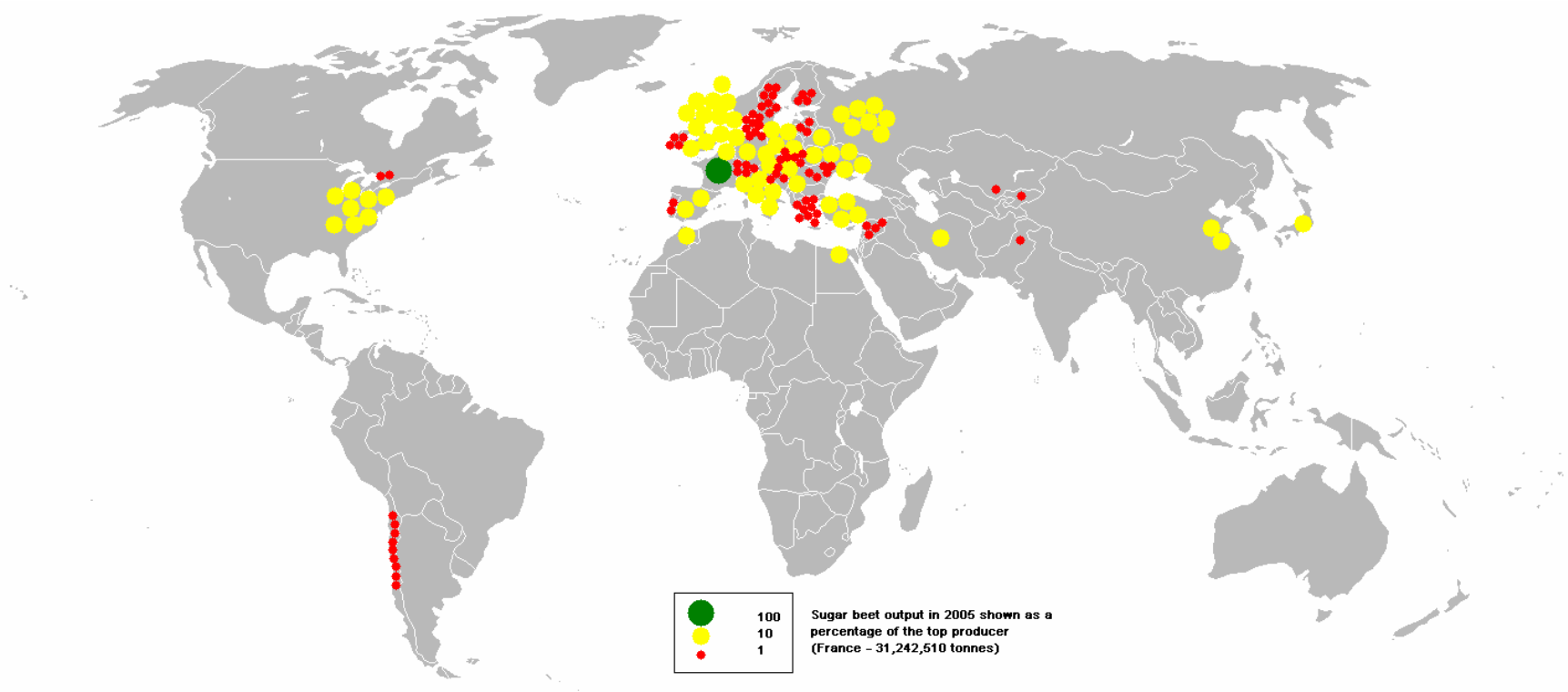
SHORT DESCRIPTION

- Family: *Chenopodiaceae*; genus: *Beta*
- C3 biennial native to South Britain;
- Taproot (1-2 kg) is white and deep-penetrating, and contains a high concentration of sucrose (15-20% by fresh weight)

ECOLOGY

•Better in deep and well-drained soil, but doing poorly on clay.
•Optimum pH 6.0 - 6.8.
•Salinity may be well tolerated after the seedling stage. Notable is the tolerance to manganese toxicity.

Growing sugar beet



30% of the world's sugar production. Mostly grown in Europe (30 – 60°N)

Growing sugar beet

- Seedbed & seeding: ploughing about 30-40 cm depth. Sowing occurs very early: mid-late February (South) or early March (Central-North). It was demonstrated that sugar yield can decline up to 50 kg ha^{-1} d^{-1} with each day delay in planting after 15 March (North Italy);

- Rotation: when possible it should follow cereals. No monoculture! high risks by nematodes and pathogens (e.g. *cercospora* and *rhizomania* ("root madness") which makes roots economically not processable;

- Plant density: optimal 10-12 plants m^{-2} 45-60 cm apart in rows;

- Fertilization requirements: N is a very crucial point, still debated. Too little N results in reduced yields as well as too much N which deceases sucrose extraction (very often payment is based on extractible sucrose!). Therefore, N dose should be determined site by site in a laboratory. On average, 100-150 kg ha^{-2} (N);

Growing sugar beet

- Weed control: poor competitor. Weeds should be controlled by four weeks after emergence. The chemical compounds are well known.
- Harvesting: from August to October depending on rainfall season and soil type. A mechanical defoliator is used to remove all the foliage prior to lifting.
- Production: average EU is 65-70 t ha^{-1}, but with a broad range: FR: 85-90; NL: 70-74; PL: 43-46; IT: 52-54 t ha^{-1}. Sucrose content about 14-20%.

Maize (*Zea mais*)

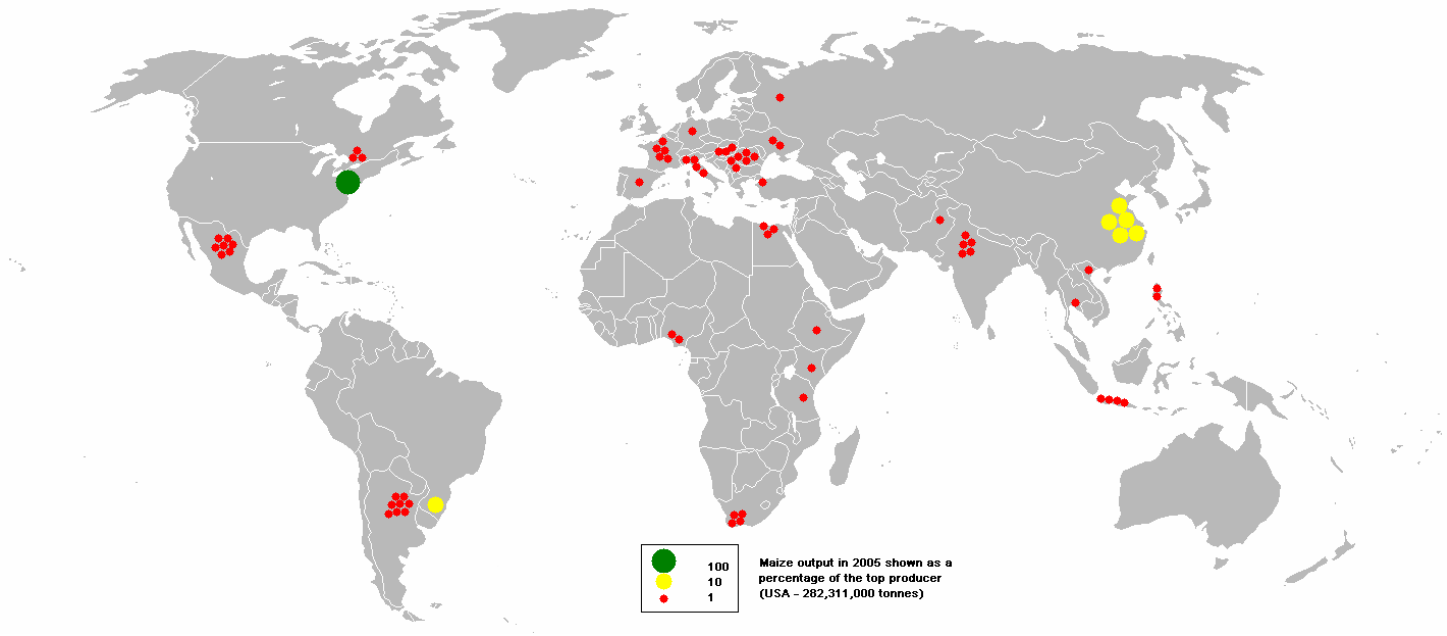
DESCRIPTION

- Family: Poaceae; Genus: Zea
- C4 plant likely native to Mexico (teosinte);
- Cultivars are divided into 6 types: pop-corn (everta), flint- (indurata), dent- (indentata), flour- (amylacea), sweet- (saccharata) and pod-corn (tunicata).

ECOLOGY

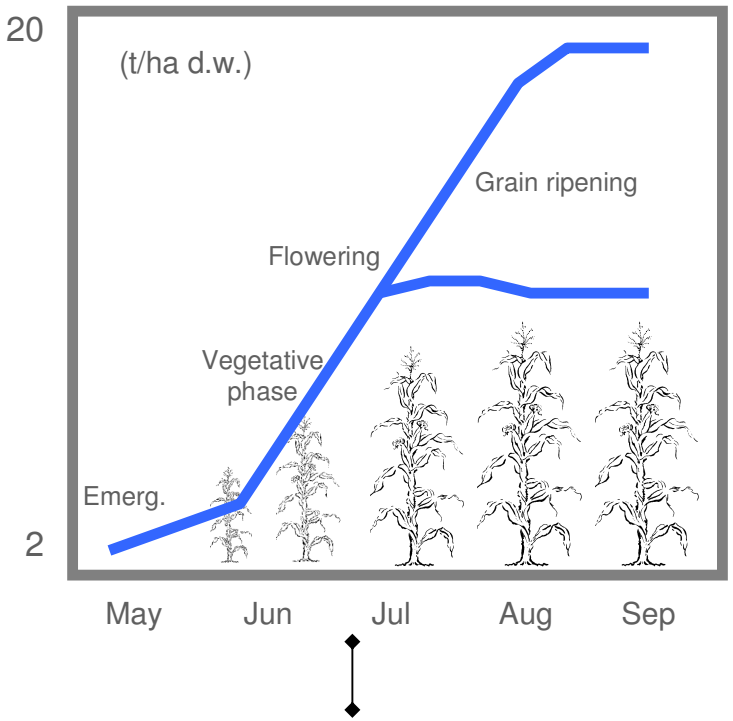
•Essentially a sub-tropical plant.
•Cold-intolerant.
•Water efficient, but very sensitive to drought (especially at flowering).
•It tolerates a great variety of soils and a pH from 4.3 to 8.7.

Growing maize



U.S. production (corn belt) is about the half of the world's harvest (about 330 Mt) followed by China (152 Mt), Brazil (51 Mt), Mexico (23 Mt) and Argentina (22 Mt)

Growing maize



- The duration of the single phases will mostly depend on temperature
- About the half of biomass is kernel

- **Seedbed & seeding**: Seeding 2-3 weeks after the average date for the last killing frost (early April in North Italy).
- **Rotation**: Monoculture is practicable but rotation (e.g. with soybean) gives several advantages.
- **Plant density**: optimal 5-6 plants m^{-2} (60-70 cm row distance); up to 9-10 plants m^{-2} as forage crops.
- **Fertilization requirements**: to produce 100 kg grain it needs 2.5 kg of N, 0.65 kg of P, 0.84 kg of K.
- **Irrigation:** generally needed, especially at flowering.
- **Weed control**: before and immediately after the emergence. Solutions are well known.
- **Harvesting**: Normally when grain moisture is 22-24%. Grain is generally ensiled.
- **Production**: up to 20-25 t/ha d.w. (about half is grain). Starch content is 70-75% of grain weight.

Potatos

WHITE or IRISH POTATO (*Solanum tuberosum*)

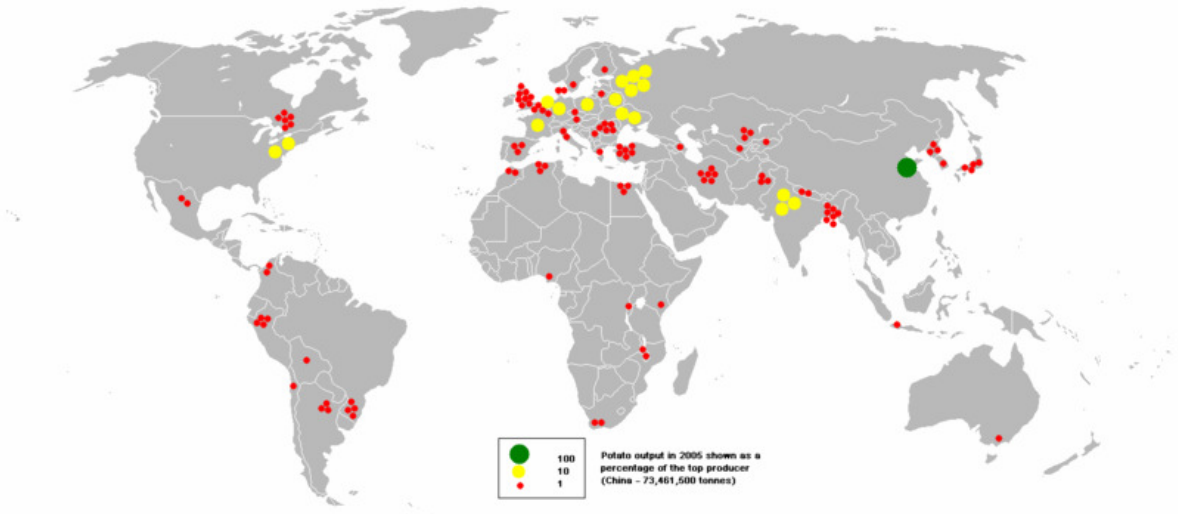
- Family: *Solanaceae;* Genus: *Solanum*; origin: South Perù
- C3 crop with a starchy tuber (4th largest food crop after wheat, rice and maize);
- 8-9 potato species include about 5.000 grown varieties (3.000 in the Andes alone). The most famous is *S. tuberosum* (tetraploid) which include the most known varieties.
- Fruit resembles a green cherry tomato containing up to 300 seeds highly toxic (large amounts of alkaloids)

SWEET POTATO (*Ipomea batatas*)

- Family: *Convolvulaceae;* Genus: *Ipomea*; Origin: Mexico-Venezuela;
- Sweet tasting and starchy tuberous roots
- Annual crop grown in warm temperate areas with sufficient water. China is the major producer (80% of world's supply).
- Frost intolerant and very sensitive to drought. 85-90% RH and 16 °C are optimal grown conditions.

Sweet potato

Growing white potato



Sowing: more often piece of potato, namely seed tubers, with 2-3 eyes, into ridges

Plant density: 6-7 seed tubers m^{-2}, 70-80 cm apart in rows.

Fertilization & weed control: high requirement of fertilizers and pesticides

Irrigation: water requirement is also high especially during flowering phase

Summary table

CROP	Cultivation area (.000 ha)	Domestication level	Input level for cultivation	Adaptability to EU conditions	Sugar yield (t/ha)
Root chicory	20	Medium	Medium	Broad	4-7*
Maize	161.000	High	High	Medium	5-8**
Sugarcane	24.300	High	High	Narrow	6-12
J. Artichoke	--	Low	Medium	Broad	4-8*
Sugar beet	4.400	High	High	Medium	6-10
Wheat	223.500	High	Medium	High	2-4**
White potato	18.200	High	High	Broad	3-6**
Sweet potato	9.000	Low	High	Narrow	1-4**
Sweet sorghum	--	Low	Low	Broad	5-8

* inulin; ** starch;

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