Marginal lands for Growing Industrial Crops

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Type

R	Document, report	☐
DEM	Demonstrator, pilot, prototype	☐
DEC	Websites, patent fillings, videos, etc.	☐
OTHER		☐

Dissemination Level

PU	Public	☒
CO	Confidential, only for members of the consortium (including the Commission Services)	☐

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Introduction

Deliverable 1.5 entitled "D1.5 – Handbook with fact sheets of the existing resource-efficient industrial crops" contains factsheets of resources-efficient industrial crops. In D1.5 a total number of twenty industrial crops have been included. This deliverable can be updated twice; in M24 (to include additional 17 crops) and in M48 (to include the project findings).

1. AMARANTH

Scientific name	Common name (s)	Family
Amaranthus L.	**Amaranth** (derives from Greek 'amaranthos' and means flowers not losing freshness), pigweed in English and many others in local languages (in Latin America, Asia and Africa).	**Amaranthaceae**

Description of the crop: The genus Amaranthus consists of nearly 60 species, cultivated as leaf vegetables, grains or ornamental plants, while others are weeds. Amaranths are erect or spreading plants, 0.3 m to 2 m tall, depending on the species, growth habitat and environment. Grain amaranth plants vary in flower, leaf and stem size and color. Stems are about 1.5 m to 2.0 m tall and flowers are very small and born in dense spikes or plumes on the top of the branches. Inflorescence and foliage range from purple, red, green to gold (Figure 1). The seeds are small and yellow, light brown or shiny black in color, in contrast to those of grain types which are cream-coloured. They have high protein content (around 13-14%) and are gluten free, unlike many cereal grains. The weight of 1000 seeds is 0.3 gr. It has a growing cycle 100-120 days.

Figure 1: Amaranthus trials in Ontario; Canada; a) Amaranthus hypochondriachus, b) Amaranthus cruentus, c) Amaranthus caudatus (http://www.omafra.gov.on.ca/CropOp/en/field_grain/spec_grains/gama.html)

Origin and research in Europe: Amaranth is originated from America and cultivated as a food crop by the Aztecs in the largest area ever grown in ancient Mexico, Guatemala, and Peru. In 1970s the crop attached interest due to its protein content that is well-suited to human nutritional needs. Currently, it is cultivated as leafy vegetable in Latin Mexico and for grain production in India, Africa and China. At present, amaranth is extensively grown as a green, leafy vegetable in many temperate and tropical regions. For grain production it is mainly cultivated in Latin America (Mexico, Central America, Bolivia, and Peru), India, China and Africa. It is imported in Europe (Germany, Netherlands and Belgium) as a food product. Recently, central European countries, such as Austria, the Czech Republic, Slovakia, Germany, Poland and Denmark, are showing an increasing interest in testing and cultivating amaranth seeds for their nutritional value and for the seed oil for cosmetic and personal care applications. The crop had been studied in the EU research project entitled AMARANTH: FUTURE-FOOD (2006-9; www.amaranth-future-food.net), while currently has been included in the project PROTEIN2FOOD (2015-20; www.protein2food.eu).

Species: Amaranths include annual or perennial plants. There are about 60 species which are cultivated for grain production (also called 'pseudocereals'), as leaf vegetables, and as ornamental plants. The amaranth grain in Asia and the Americas, include the three species, *Amaranthus caudatus*, *A. cruentus*, and *A. hypochondriacus*. Four species of Amaranthus are documented as cultivated vegetables in eastern Asia: A*. cruentus, A. blitum, A. dubius,* and *A. tricolor*. In Brazil, green amaranth was, and to a degree still is, frequently regarded as an invasive species as all other species of amaranth (except the generally imported *A. caudatus* cultivar). *A. caudatus* and *A. hypochondriacus* are also well-known as ornamental plants.

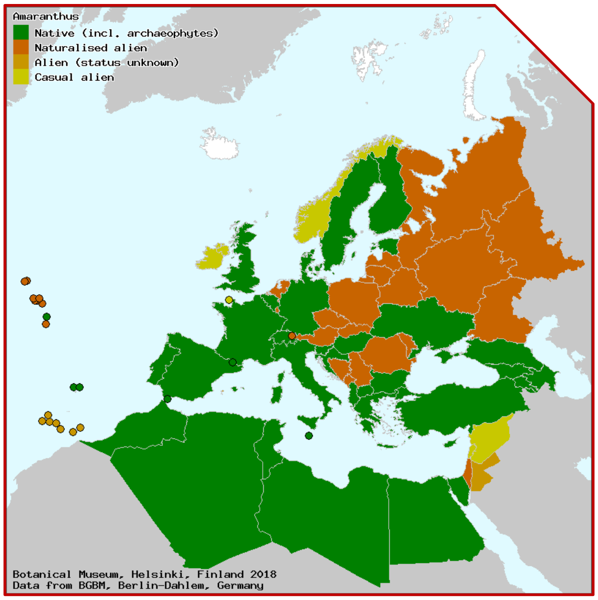

Figure 2: Distribution of *Amaranthus spp.* in Europe and North Africa (source: Euro+Med database project; https://ww2.bgbm.org)

Soil and climate preferences: Amaranth is highly tolerant in arid environments and abiotic stress (drought, salinity, alkalinity and acidic poor soil) conditions. It is adapted to a variety of soil types, including marginal soils, but performs best on fertile, deep and well-drained loamy soils. The optimum soil temperature at planting is 18^0-24^0C. Plants need an air temperature above 25°C for optimum growth, while they stop to grow at temperatures below 18 °C. It is a cold sensitive crop. The number of growing degree days during the growing season is a major determinant of amaranth plant growth. Lower temperatures and shorter days will induce flowering with a subsequent reduction in leaf yield.

Diseases and insects: Amaranth is susceptible to a number of insects although the plants are able to recover after feeding by most leaf-chewing insects. Tarnished plant bug, leaf miners, flea beetles, grasshoppers, caterpillars and amaranth weevils, are potentially significant insect pests of amaranth. Flea beetles damage young leaf tissue. Disease problems may develop in large monoculture production systems. Damping-off of young seedlings caused by Pythium can be a problem under some environmental conditions, as well as Rhizoctonia and stem canker, caused by Phorma or Rhizoctonia. Amaranth grows slowly during the first few weeks therefore it is very vulnerable in early weeds. Weeds can be controlled by weed harrowing or pre-planting herbicide spraying, although there are no selective herbicides for amaranth. Increasing crop density could also minimize the weed infestation. Once amaranth gets 15-25 cm tall, it begins to grow rapidly and suppresses late emerging weeds.

Soil preparation and sowing: A fine and firm seedbed is needed for sowing because amaranth requires good seed contact with the soil for rapid germination and emergence, while adequate soil moisture must be maintained at the seeding depth throughout the initial establishment. Due to its small size of the seeds there are mixed with sand at sowing (1:2). The sowing depth should be 0.5 to 1cm. The establishment could be done either directly by sowing on the field or in seedbeds. The recommended seed rate is 2.5 kg/ha of seeds. Sowing can be done either directly into the soil with broadcasting the seeds, or sowing them in shallow rows. The distance between the rows should be 1.5 m and within 30 cm. In order to get this a thinning of plants is carried out when the plants are 15 cm tall.

Water and fertilization needs: Although it is a drought resistant plant, it performs optimally under irrigation, which is critically required in concrete stages, such as plant emergence. Severe drought induces early flowering and stops the production of leaves. In contrast, amaranth does not respond significantly to very high amounts of irrigation water because it cannot withstand waterlogging due to its relatively low capacity for water consumption. Nitrogen fertilization significantly affects the amaranth plant growth. High levels of nitrogen are necessary for the regrowth of leaves after harvesting. Nitrogen requirements may vary from 50 to 200 kg N/ha and the requirements also differs, depending on the species. Phosphorus and potassium can be applied at lower levels.

Yields: The fresh leaf yields varied from 4 to 14 t/ha, however, in recent research yields up to 40 t/ha have been measured. For leaf production the harvests can take places every two weeks, after the first cut. If the plants are treated correctly, it should be possible to harvest leaves every two weeks. The grain yields varied from 1800 to 3000 kg/ha.

Harvesting and storage: Seed heads are harvested just before they become dry and brittle. Amaranth should be harvested after a killing frost in order to reduce yield losses and maximize seed germination (there are no approved desiccants for amaranth). Harvest before a killing frost is not recommended because the harvested material has high moisture content that makes storage difficult and increases drying costs. The plants are usually harvested by hand but can also be harvested by combine harvesters. A regular combine can be used if fitted with appropriately sized separator screens. Row headers perform better at harvesting amaranth than reel heads. Shattering during the cutting process can cause seed losses. In field trials it is reported that hand-harvested plots yielded 25% to 30% higher than plot combine harvest yields, due to seed losses caused by mechanical harvesting. Germination was approximately 20% higher for hand-harvest seed than for plot combine harvest seed. Maximum moisture for storing the grain is approximately 11 %. It is important to keep properly dried seeds in a closed container to avoid contamination.

Figure 3: View of manual harvest of Amaranthus panicles in Huitzo, Oaxaca, Mexico.

Uses: Amaranth grains can be used for foods and its vegetative parts can be used for animal feed (e.g., forage and silage) or green manure. Grains contain high levels (12.5-17.6 % on dry matter) of nutritionally favorable protein, gluten-free, which helps those who suffer from nutritional allergies. It also contains unusual quality of starch and high-quality oil rich in squalene. The total lipid content of grain amaranth ranges from 5.4 to 17.0% of dry matter, with high level of unsaturation (about 75%), containing almost 50 % linoleic acid.

Due to the content of potential health-promoting compounds such as rutin and nicotiflorin, amaranth is considered a ‘natural biopharmaceutical’ plant. The red-colored vegetative tissue produces high levels of betacyanin pigments that can be used as natural food colorants. Amaranth has been attracting worldwide attention as a high-potential new crop with multiple uses. Recent scientific publications on novel applications of amaranth grain and its fractions suggest the crop has a very promising future.

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3. PROTEIN2FOOD project; www.protein2food.eu
4. Euro+Med database project; https://ww2.bgbm.org

2. CALENDULA

Scientific name	Common name (s)	Family
***Calendula officinalis* L.**	**Calendula, Scotch-marigold, pot marigold, ruddles**	**Asteraceae**

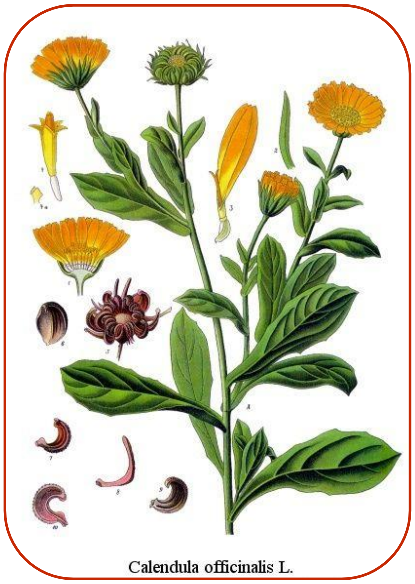

Figure 1: View of the crop

Description of the crop: Calendula is an herb reaching a height of 40-70 cm at maturity depending on cultivar. Although is a biennial crop it is cultivated as annual crop. It has a deeply penetrating tap root. The leaves are elongated, spatulate, light green and tomentose hairy (Figure 1). The inflorescence is an orange, terminal capitulum of 4-7 cm in diameter. Flowering begins in mid-June and seeds ripen in the beginning of August. The plant continues to flower till the first autumn frosts. It is required a period of 98 to 150 days from sowing to harvesting. The weight of 1000-seeds is varied from 5 to15g.

Origin and research in Europe: Although *Calendula officinalis* is considered native of the Mediterranean area it is grown widely across Europe (Figure 2). It has been cultivated for many years as an attractive garden plant, although the plant has several other uses such as: oil productions (calendic acid), essential oils, pigments from its flowers and medicinal applications.

At late 1980s it was proposed as new oil crop for the chemical industry. In CARMINA[5,8] EU project entitled "Calendula as Agronomic Raw Material for Industrial Applications", the cultivation and usage of the crop was developed. It was also studied the AIR project entitled "Vegetable oils with specific fatty acids" (1994-6) in comparison with another four oil crops.

Varieties: A number of calendula genotypes had been compared and evaluated in VOSFA program showed considerable diversity in flower structure and site stem branching crop height, flowering period and maturity. Several constraints remain to be solved before this crop can be widely grown in Europe. Improved varieties should be developed for Europe by applying modern breeding technology in which studies on field trials should be carried out in order the best in terms of yields and quality to be selected.

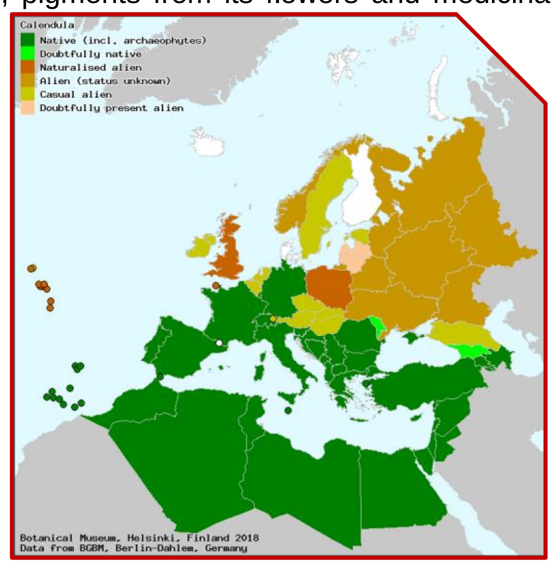

Figure 2: Figure 1: Distribution of *Calendula officinalis* L. in Europe and North Africa (source: Euro+Med database project; https://ww2.bgbm.org)

Figure 3: Fields of calendula in southwestern Germany; http://sustainableherbsproject.com/explore/supply-chain/production/cultivation/

Soil and climate: The crop is well adapted to temperate climatic zones in Europe, although it is originated from Mediterranean region.

It prefers soils with pH 5.5 to 7, but can survive in soils with pH from 4.5 to 8.3. It develops well in shallow soils with soil depth 20-50 cm as well as in low fertility lands.

Sowing: Calendula should be sown in spring, usually early to mid-April. It is considered less sensitive to frost compared to other spring crops (sugar beets and flax). The emergence is normally rapid and from mid to late April the plantation can have a nice coverage. In good seed lots the germination capacity varies from 60-80 % and in the field an emergence from 40 to 60% could be anticipated. Camelina seeds are small and thus a fine and firm seedbed is required at sowing. Calendula should be sown at a depth of 1-2 cm similar to that for oilseed rape and linseed. Although, the target plant population[2,4] is 60 plants/m², good yields have been achieved from 40 plants/m². Normal row spacing with commercial seed drills is 12-25 cm, although wider, 50 cm rows are used for mechanical weeding systems. Typical seed rates are 7-12 kg/ha. A number of pre-emergence residual herbicides were shown to be crop safe and glyphosate is one of them. The lack of a safe post-emergence material limits weed control options in the crop[3].

Water and fertilization needs: In terms of fertilization calendula requires 50-100 kg/ha of nitrogen, 25-75 kg/ha phosphate (P_2O_5) and 50-100 kg/ha potassium (K_2O). As with all crops, poor fertilization can result in uncompetitive plants and increased weed problems and an excess of fertilizer, particularly nitrogen can contribute to increased damage by plant diseases as well as lodging. The need for fertilization depends on the nutrients status of the soil and the fields' previous cropping history. Off takes of nutrients in seed are not high, so minimal replacement with inorganic fertilizer or organic manures is all that is required. A light dressing of nitrogenous fertilizer (50 kg/ha) has been found to increase biomass but not necessarily affect directly the seed yields.

Yields: The average yield of dry petals could vary from 200-300 kg/ha, while at complete inflorence could vary from 500 to 800 kg/ha. At present, the seed yields of 1000 to 1500 kg/ha (200 to 300 kg oil per ha) that could be obtained on farm scale, but with improved production systems are with improved varieties/genotypes that seed yields could be twice higher and thus calendula could be an attractive oilseed crop for the European farmers. Calendula seeds contains 18-22% oil and 55-60% of the oil is corresponding C18:3 (calendic fatty acid)[6]. In CARMINA project the oil content in the compared varieties varied 16.3% to 19.2%.

Harvesting: Calendula produces flowers over a long period and thus the optimum harvest date is difficult to be defined ensuring the highest seed yields and the lowest seed shedding[6]. It is recommended to the growers to apply diquat and the harvesting could be arranged 5 to 7 days later. The most recommended harvest method is direct combining. Swathing is not recommended due to seed shedding and of short crop plant height.

Pest and diseases: Few pests have been identified and reported in calendula fields. Botrytis has been reported in plantations when the humidity is increased. Mildew has also been reported, although its effect on seed yields is unknown. Sclerotinia has been also reported in crops and has been found in harvested seed lots. Applications with Vinclozolin (Ronilan) during flowering or Uprodione (Rovral) at the stage of leaves defoliation can control successfully botrytis and sclerotinia, respectively. In general in order sclerotinia to be controlled it is recommended calendula to be cultivated only every six years on the same field and not to be part of intensive rotations with other susceptible crops such as oilseed rape and sunflower.

Uses: Calendula is usually cultivated as medicinal and ornamental plant[1]; therefore limited information is available on the potential of this species as an oilseed crop. Calendula has been selected as an interesting oilseed crop due to it high content of calendic acid that could be used in paint manufacture, varnishes, cosmetics, industrial nylon products and for products with wound healing properties. The chemical structure of calendic acid, containing three reactive conjugated ethylenic bonds and an octatrienoic acid isomer, makes it a potentially useful compound within industrial products and for chemical modification. Market opportunities have been identified for calendula oil as an ingredient for the production of reactive diluents and oil based alkyd resins which are applied in high solid paints and as a substitute for Tung oil, which is currently imported into the European Union. Replacing imported Tung oil would require at least 10 000 ha of Calendula to be grown in Europe. Especially ethyl and isopropyl Calendula oil esters showed good properties including low viscosity and good drying performance. Furthermore a shortening of the drying time of about 35-40% compared to conventionally prepared formulations was achieved. The reduction or even the substitution of organic solvents in the coating processing by reactive diluents derived from renewable material would be an important contribution to the necessary reduction of volatile organic compounds.

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3. CAMELINA

Scientific name	Common name (s)	Family
***Camelina sativa* L. (Grantz)**	**Camelina**, gold-of-pleasure, false flax, wild flax, linseed dodder, German sesame and Siberian oilseed.	**Brassicaceae**

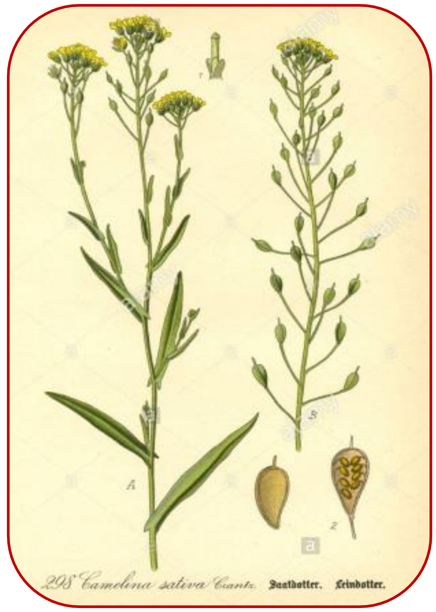

Figure 1: *Camelina sativa* L[3].

Description of the crop: Camelina is an annual winter and/or spring oilseed crop with plant height varying from 30 to 120 cm. Its stems have branches that at the maturity are woody. Its leaves are 2-8 cm long and 2-10 mm width. Camelina flowers have four petals, pale yellow in color and they produce fruits that contain small seeds, orange in color. Seeds are very small and 1000 seeds weight from 0.8 to 2 gr. There is no seed dormancy in camelina[1].

Origin and research in Europe: Camelina is native to southeast Europe and southwest Asia[2]. It is naturally widespread in Europe (Figure 1). Nowadays, it can be found either wild or cultivated in Europe, Asia, North and South America as well as in Australia and New Zealand. It is well adapted in cold semi-arid climatic areas. It is a winter crop but in mild climates like the Mediterranean region it can be grown also as spring crop. It used to be grown in Northern and Eastern Europe until 1940s when it was replaced by rapeseed. The last two decades camelina has been reintroduced at research level in Europe in the view of several research projects starting from the project entitled "Camelina sativa: An alternative oilseed crop"[5]. The research activities continued with two projects that included camelina in their research activities namely ICON[6] and ITAKA[7]. In the latter project camelina was grown on marginal lands in Spain. Currently, two H2020 projects are working on camelina: COSMOS[8] & BIO4A[9]. Photos from COSMOS field trials at several stages of growth in Greece and Poland are presented in Figures 3, 4 & 5.

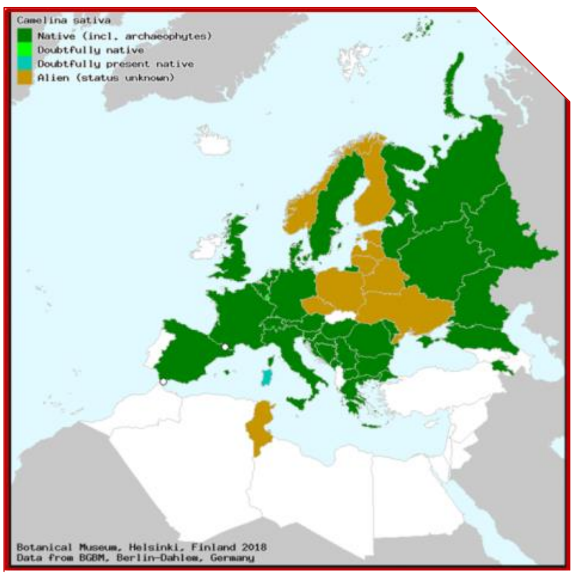

Figure 2: Distribution of *Camelina sativa* L. in Europe[4]

Varieties: The varieties[1] that have been reported are: a) in North America: Blaine Creek, Suneson, Platte, Cheyenne, SO-40, SO-50 and SO-60 and b) in Europe: Epona, Celine, Calena, Lindo, Madonna, Konto and D.Tagliafierro. In the view of COSMOS project a high number of new varieties are being tested and compared on screening trials located in Greece, Italy, Poland and Canada (Figure 3). The tested varieties are: eighteen spring varieties provided by Linnaeus Company in Canada (Midas, 14CS0886, 14CS0887, 13CS0787-05, 13CS0787-06, 14CS0787-08, 13CS0787-09, 13CS0787-15, 13CS0789-02, 13CS0787-22, 13CS0787-27, 16CS1040-04, 16CS1043-01, 16CS1047-01, 16CS1043-04, 16CS1043-05, 16CS1040-01, 16CS1043-02), three varieties provided by Poland (UMW; Luna, Omega and Mazurka), a variety provided by Wagenigen Research Institute and a variety provided by USDA (Joelle)[8]. In ITAKA project more than 20 varieties had been compared in Spain on marginal fields with total size higher than 15,000 ha[10].

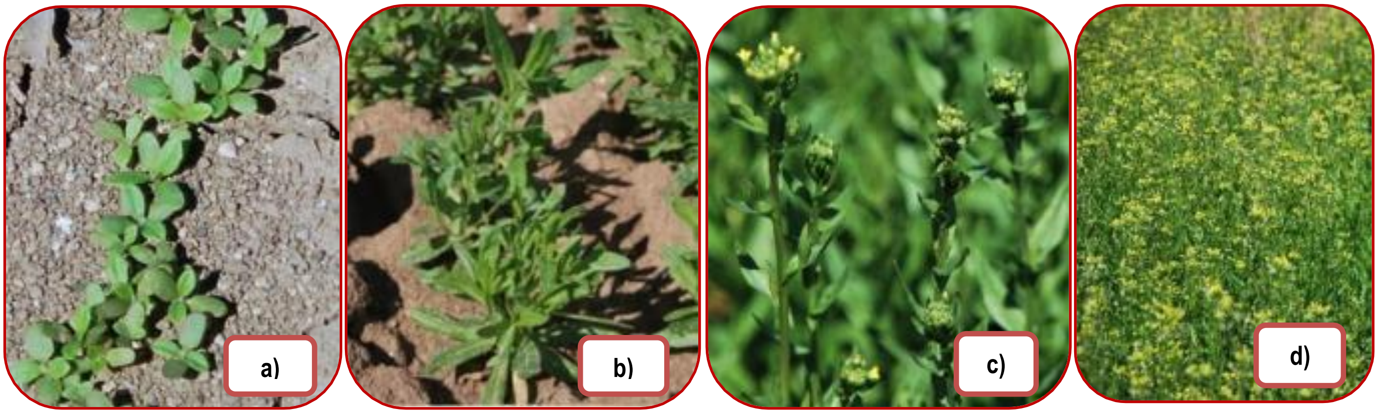

Figure 3: View of the camelina at several stages of growth: a) few days from emergence, b) early stages of growth, c) beginning of flowering, d) full flowering (source: CRES; Cosmos project)

Soil and climate preferences: In general, camelina species are best adapted to cool temperate and semi-arid climates. Camelina grows very well on well-drained light (sandy), medium (loamy) and heavy (clay) soils. Compared to other oilseed crops, like rapeseed and sunflower, camelina shows better performance in semi-arid regions due to its drought and frost tolerance[11,12]. Camelina can survive conditions of dry soil, low rainfall and frost due to its short growing season (90 to 120 days). It can be grown well in nutritionally poor soil. Thus, it is considered as an oilseed that can be grown on marginal lands[10,13].

Diseases and insects: Camelina is considered a pest and disease resistant crop[14], compared to other oilseed crops. More specifically, camelina is highly resistant to blackleg (*Leptosphaeria maculans*), which is a major disease of canola and other Brassica crops. Although camelina is susceptible to sclerotinia stem rot (*Sclerotinia sclerotiorum*), major outbreaks are uncommon. Few insects appear to cause damage to camelina and thus the use of insect control measures is rarely reported. The canola-damaging insects [flea beetles (*Phyllotreta cruciferae*, Goeze), cabbage seed pod weevil (*Centorhynchus obstrictus*, Marsham), and Brassica aphid complex] have not been reported to cause economic damage to camelina[14].

Figure 4: View of camelina trial in Poland (Source: UMW; COSMOS project)

Soil preparation and sowing: Minimal seedbed preparation is needed to establish camelina. There is no registered herbicide for camelina. It is recommended 4 to 6 kg/ha[15] to be applied at sowing. The soil depth at sowing should not be higher than 2 cm. Soil depths between 6 and 13 mm are the most recommended[16]. In COSMOS project two plant densities are being tested: 250 and 500 seeds per m^2 (the distances between the rows are 15 cm). The results that have been collected so far indicate that higher seed yields can be obtained at the high plant density

(COSMOS project; 500 seeds per m^2)[8]. In the same project several sowing dates have been tested (from October to April in the Mediterranean region and from end March till early May in northern Europe). In Greece it was found that the best sowing dates were from beginning of December till end of February.

Water and fertilization needs: Camelina has low nutritional requirements. 75 kg N/ha are enough to cover the nitrogen needs of the crop, while higher doses of nitrogen fertilization can increase the lodging problems and decrease the oil content of the seeds[17]. It is considered as crop with high tolerance to drought and heat.

Seed Yields: In COSMOS project the mean seed yields that have been recorded so far are 2 t/ha (varied from 1 to 3t/ha)[8]. In ITAKA project the reported yields varied from 0.5 to 2.5 t/ha[10]. The oil content (%) of the seeds vary from 38 to 42%. 90 % of the camelina oil contains unsaturated fatty acids, including a 30-40% fraction of alpha linolenic acid, another 15-25% fraction of linoleic acid, about a 15% fraction of oleic acid and around 15% eicosenoic acid[10].

Figure 5: View of camelina field ready to be harvested (source: CRES, COSMOS project)

Harvesting and storage: Camelina can be harvested with unmodified combines and is usually direct-combined standing but can be swathed and then combined with similar seed yields[18]. The harvesting should start when 75% of silicles are dried[19]. Mature pods are dark tan or brown. The combine settings should be similar to those used for canola or alfalfa seed, but the combine fan speed should be reduced to minimize seed losses. Small-opening combine screens designed for alfalfa seed are effective in separating camelina seed and hulls. Unlike other members of the mustard family, camelina pods hold their seeds tightly, and seed shattering is not generally a problem. Most camelina cultivars are resistant to shattering.

Figure 6: View of meal, oil and seeds of camelina (on the left) and of crambe (on the

Uses: Camelina oil can be used for both food and no-food products. Its seeds have 38-42% oil and 28-32% protein[10]. Its antinutritional content is low; > 40 mmol/kg of glucosinolates and > 5 mg/g of sinapine. Camelina oil is considered as high quality edible oil, due to it's the relatively high percentage in omega-3 fatty acids and low in saturated fatty acids. Camelina oil contains gamma tocopherol (vitamin E), which acts as an antioxidant and increases the stability and self-life of camelina oil compared to other omega-3 oils[20]. Camelina and crambe have been selected by COSMOS project (Figure 6) as oilseed sources of medium-chain fatty acids (MCFA, C10–C14). In Europe, currently, these fatty acids are obtained by the imported coconut oil and palm kernel[8]. These fatty acids are used by the oleochemical industry for the production of surfactants and detergents, lubricants, plasticisers and other products. The prices for these medium chain fatty acids are higher than those of the more common long chain fatty acids such as palmitic, stearic and oleic acid, but also much more volatile[8].

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4. CAPER SPURGE

Scientific name	Common name (s)	Family
Euphorbia lagascae SPRENG	Caper spurge, wild spurge, moleplan	Euphorbiaceae

Description of the crop: Caper spurge (*Euphorbia lagascae* SPRENG) could be an annual, biennial or in some cases perennial crop. In several articles the crop it is confused with *Euphorbia lathyris*. As an annual crop it requires 110-120 frost free days to mature. It can be up to 1 m high with smooth light green stems 30-50 cm long. Usually, the stems are erect but when the apical dominance inhibited braches are been developed that producing a big amount of white sticky latex. The leaves surfaces can be glaucous, covered with a greyish waxy coating or glabrous. The leaves are ovate-linear below (Figure 1) and narrowly lanceolate above and subtending flower clusters broader. The flowers (Figures 1 and 4) are sub-cordate, ovate-lanceolate and triangle lanceolate and greenish yellow. The fruits are usually 3-lobed, sub-globose, up to 1 cm long. The capsule contains three or four seeds and it is ovate, acutely ribbed and scarlet in varied shades.

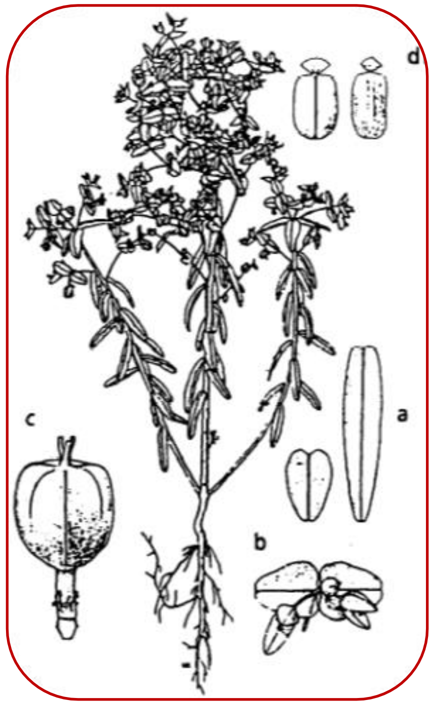

Figure 1: Drawing of Euphorbia lagascae SPRENG[1]

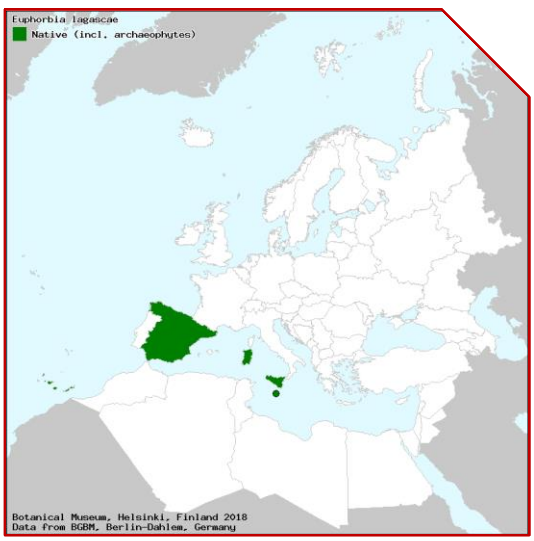

Figure 3: Distribution of Euphorbia lagascae SPRENG in Europe[2].

Origin and research in Europe: Caper spurge is native to the Mediterranean area and it is particularly present in Spain and Italy[2] (Figure 2) but less widespread than *Euphorbia lathyris* which can be found from Southern to Northern Europe, as well as in North America. It occurs in the arid southeast and in the entire coastal region of Cadiz and grows spontaneously in cultivated field around towns. In Italy can be found as wild species in Sardinia. *E. lagascae* has been introduced in North America and North Europe. From late 1990s and onwards caper spurge had been included in a few EU research projects: a) The development of euphorbia lagascae as a new oil crop within the European Community[3], b) Agronomy and breeding of vernola[4] (*Euphorbia lagascae* L.), c) IENICA Network[5] and d) Crops2Industry[6].

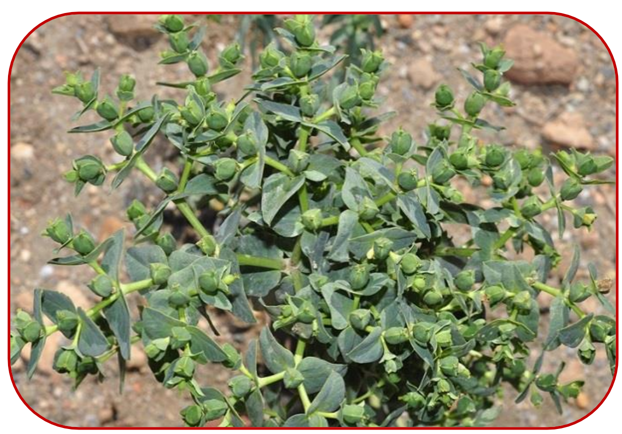

Figure 2: View of the caper spurge with the fruits[7]

Varieties: The breeding activity on this species is still in its infancy. The targets of future breeding programmes should contain: a) decrease of seed shattering, b) improve resistance to herbicides and c) increase of seed yields. In Spain, caper spurge mutants have been developed with increased number of seeds per capsule that were in some cases up three times higher compared to the wild types containing three seeds per capsule. Although, the seed shattering trait has been improved, the development of non-shattering varieties needs further breeding efforts.

Soil and climate preferences: Caper spurge prefers fallow lands rich in nitrogen. It seems tolerant to damp sites of saline nature[8]. Caper spurge can be considered a drought tolerant plant. Excess irrigation may generate too much greenness of stems, scalar seed maturation, and massive release of latex and weed spreading. Otherwise, prolonged water stress periods may lead to vegetative re-growth in autumn when rainfall occurs[9].

Figure 4: View of the crop from early stages to harvesting[9]

Soil preparation and sowing: The optimal sowing time is from April to May and a quantity of 10 to 30 Kg seeds per ha is needed. The distances between the rows should be 30cm (Figure 4). The seed yields are increased by an early sowing in conjunction with a wide row spacing[10].

Seed Yields: Field trials had been conducted in Spain in which the tested parameters were: sowing time (autumn or spring), sowing densities (36.000 to 143.000 plants per ha), field location (winter mild coastal and cold winter inland areas), irrigation and nitrogen application. The highest seed yields have been recorded in the coastal locations of Spain with 0.4 to 1.6 tones seeds per ha and with an average oil content of 44% (63% of vernolic acid)[11]. In field trials carried out in the Netherlands the seed yields came up to 1.2 tons per ha and almost 25% losses occurred due to dehiscence[12]. Serious seed losses for caper spurge have been recorded in field trials carried out in North Dakota[13] due to chattering.

Harvesting and storage: Caper spurge presents significant problems at harvest due to scalar maturation. These problems comprise indeterminate growth and consequently a long period to reach capsule dehiscence. Moreover the foliage is rich in latex, that is vesicant and irritant and its handling can be critical, especially for the operators. It is particularly important to define the right time of harvest. Concerning the equipment, various field researches on the harvest of Euphorbia lagascae have tested the suitability of different harvesting machines. Combine harvester seems not feasible due to high moisture content at harvest time. The best machine was the pea harvester since caper spurge being fairly similar to green peas. To avoid the blockage of the threshing drum, the machine can be equipped with a special cutter-bar table. Thanks to this tool, the sticky latex does not cause problems and no gum build-up occurs.

During threshing, even if the process is rough and designed for pulses crop, there are no evident sign of seed damage. After drying the organic matter up to a moisture content of 8%, the seeds can be cleaned through an air screen cleaner coupled with a brushing machine[12].

Uses: Wild spurge has been grown for very different purposes, being medicinal, ornamental or as a repellent for rodents in orchards[14]. The oil is the marketable product of wild spurge, nonetheless its industrial use is still little known. Along with medicinal uses, studies dated back to 1976 by Nobel Prize M. Calvin suggested to use it for biofuels, since its oil composition of wild spurge being very close to that of diesel oil. The oil characterisation of the crop revealed interesting potentialities for using it to soaps, detergents, lubricants, paints and cosmetics. The oil has high levels (up to 70%) of epoxy fatty acids, as vernolic acid, that make it suitable for epoxy coatings and resins[15]. It is the most known epoxy oleic acid from natural sources along with coronaric acid that indeed is the principal fatty acid (up to 90%) of seed oil of Bernardia pulchella. Vernolic acid is an isomer of coronaric acid and both are biosynthetically related to linoleic acid. The epoxy acids are the best to produce paints and coatings; in fact vernolic acid is used as a drying solvent in alkyd resin paints, a plasticizer or additive in polyvinyl chloride (PVC) resins and possibly in pharmaceutical applications. Paints formulated with vernolic acid would greatly reduce volatile organic compound (VOC) air pollution that now occurs with volatilization of alkyd resins in conventional paints. Additional uses are in the treatment of skin diseases, ulcers and warts, as well as cancer tumors and intestinal parasites. Some of the compounds of these plants are polycyclic and macrocyclic diterpenes with several biological effects such as, cytotoxic, antiviral, multi drug resistant reversing activity, antitumor, anti-leishmanial and anti-inflammatory.

Figure 4: Fruits and seeds of caper spurge[16]

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5. CASTOR

Scientific name	Common name (s)	Family
***Ricinus communis* L.**	**Castor**, castor oil; castor oil plant; castor-oil plant; palma christi	**Euphorbiaceae**

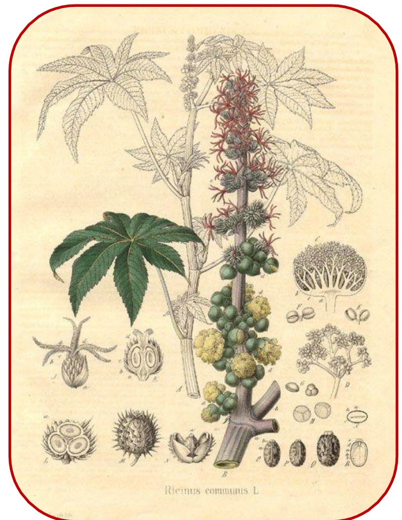

Figure 1: *Ricinus communis* L[1].

Description of the crop: Castor is a valuable oilseed crop that can be either annual or perennial (small tree). The crop varies greatly in its growth (80 cm to 3 m high) and appearance (shape, color). It can be found in many sites worldwide as native species. The annual growing cycle depends on the cultivation site and can be up to 180 days when it is grown in India and between 120 and 150 days in the Mediterranean region. It has glossy leaves 15-45 cm long, usually palmate, with five to twelve deep lobes with coarsely toothed segments (Figure 1). The colors of the leaves and of the whole plant can vary from red to green. The panicles are racemes, which are erect up to 40 cm long, have male flowers towards the base, and female ones towards the top[2]. It is a cross-pollinated crop that under natural conditions can exceed 80%[3], but the actual level of cross pollination depends on genotypes and environmental conditions. The flowers have 3-5 sepals and no petals. Each raceme has many capsules (80-120 per raceme), each one containing three seeds. The weight of 1000 seeds varies from 100 to 150 gr. The crop from emergence to seed maturity is presented in Figure 2.

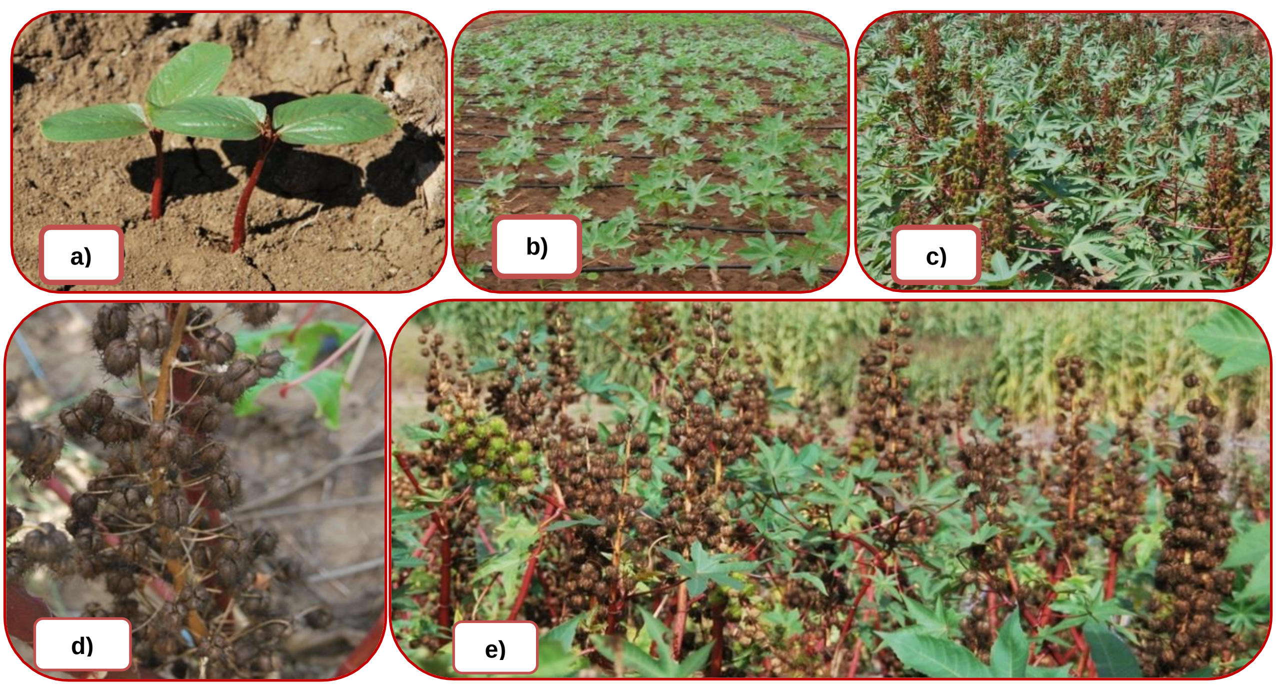

Figure 2: View of castor at: a) emergence, b) early stages of growth, c) full flowering, d, e) mature racemes (source: CRES; Greece)

Origin and research in Europe: Ethiopia is considered to be the most possible site of origin due to the presence of high diversity of castor[4]. Castor is indigenous to the southeastern Mediterranean Basin, Eastern Africa, and India, but is widespread throughout tropical and subtropical regions[5] as ornamental crop. Castor is being reported as a crop with tolerance to insects and diseases, nematodes, drought and heat, high and low pH, poor soil and slope[6]. It is commercially grown in India, China, and Brazil[7]. Currently, more than 3 million hectares of land is planted with castor around the world[8]. In 2015 the global castor oil seed production was 1.8 million tonnes and the main producer was India with 1.55 million tonnes[9]. Although the crop can be cultivated in the Mediterranean region, it is found only on experimental and demonstrative fields. It should be pointed out that Europe is one of the main importers of castor oil. It has been studied in a few EU research projects, the most recent being EUROBIOREF[10], where it had been compared with other oilseed crops (cuphea, lesquerella, lunaria, safflower, sunflower and rapeseed).

Figure 3: Comparison between two local Greek genotypes (one green and one red) and a short high yielding hybrid (Source: CRES)

Varieties: Several varieties and hybrids are available worldwide that differ greatly in terms of plant architecture and growth habit (Figure 3). Nowadays, the research has been focused on developing short annual varieties and/or hybrids with increased seed yields, uniform seed maturity, increased tolerance to pests and diseases and increased performance to mechanical harvest. The last years, a number of hybrids have been tested in the Mediterranean region (developed in Israel by KAIIMA company) with very good seed yields that in some cases reached around 5 t seeds[11,12] per ha. In this research work the local genotypes (Figure 3) although developed higher plants their seed yields were lower and the seeds had uninform maturity.

Soil and climate preferences: The crop can be grown on low rainfall and fertility conditions and it is considered appropriate for drying farming. In India the crop is being grown without irrigation. Castor is a hardy crop and can be grown in a wide range of climates of warm regions with a rainfall of 250-750 mm. It performs best in moderate temperature (20-26^{o}C) with low relative humidity and clear sunny days throughout the crop season. Areas with temperature higher than 40^{o}C or lower than15^{o}C are not conducive for castor cultivation. A frost free climate is mandatory for the crop. It is a drought resistant crop due to its tap root and due to light reflecting characteristics of its stems and leaves that reduce heat load and improve survival under moisture stress. At flowering and capsule formation stages high rainfalls have negative effects since they help the appearance of botrytis disease. The crop can be grown successfully on most of the soils apart from heavy clay and poorly drained soils. Moreover, soils with low water holding capacity like the sandy soils are also not appropriate for castor cultivation. Soils with pH > 9.0 or < 4.0 should be avoided. Moderately fertile soils are preferred as high fertility induces excess vegetative growth, prolonged flowering and delay the maturity, leading finally to poor yields.

Diseases and insects: Castor is affected by several diseases; however, only a few are regarded to be of economic importance[12] and thus it is considered as a crop with tolerance to most diseases. The three major diseases affecting castor are: gray mold (Botryotinia ricini G.H. Godfrey or Amphobotrys ricini N.F. Buchw. in its anamorphic), vascular wilt (Fusarium oxysporum f.sp. ricini Nanda and Prasad), and charcoal rot (Macrophomina phaseolina [Tassi] Goid.). Gray mold is one of the most serious castor diseases worldwide and can be found in racemes when the moisture content is increased (rainfalls) at the flowering phase. The castor seedlings are susceptible to vascular wilt when cultivated in wet soils.

Soil preparation and sowing: A deep ploughing is necessary, for weed control and conserving moisture followed by harrowing. The appropriate plant density strongly depends on the cultivated genotype (high, short) growth habit and plant architecture[13]. It has been recommended to sow in rows with 1 m distance between the rows and 25 cm within the rows; 15 kg seeds/ha for sowing[14]. In general, it can be said that the distances between the rows should be large varying from 60 to 100 cm, while within the rows should be between 15 and 60 cm (12-15 kg seeds per ha). Castor has an initial slow growth rate that increase a month from sowing. The soil depth at sowing varies according to the soil type from 6 to 10 cm. Shallow soil depth at sowing (6 to 8 cm) is recommended in heavy soils. The soil temperature at sowing should be higher than 12^0C.

Water and fertilization needs: Although castor tolerates moisture stress it responds positively when it is grown under irrigation[15]. The crop performance is poor when the crop experiences moisture stress from seedling to flowering stages and during this critical period 2-3 irrigations are needed. When the water is limited it should be irrigated once in the beginning of the flowering phase. During the maturity phase irrigation should be avoided since it prolongs the vegetative phase and results in delayed maturity of the seeds. Castor exhausts the soil quickly. It has been estimated that for the production of 2000 kg seeds/ha is removed from the soil: 80 kg/ha N, 18 kg/ha P_2O_5, 32 kg/ha of K_2O, 13 kg/ha CaO, and 10 kg/ha of MgO[16]. In India it is rotated with ragi, groundnuts, cotton, dryland chili pepper, tobacco or horsegram[17].

Figure 4: Castor harvesting

Seed Yields: Seed yields vary according to the cultivated variety/hybrid and the cultivation site. Generally, seed yields 2-5 t/ha are being reported[11]. The oil content of the seeds is quite high (50% or even higher)[12].

Harvesting and storage: In South Europe a period of 120 -150 days is needed for the crop to reach maturity (first half of September).

The harvesting should be done when the capsules turn to yellow-brown. The seeds do not mature at the same time (Figure 1) and in most of the cases the plantations should be sprayed in order the growth to be stopped and the harvesting to be scheduled. Castor seeds are very susceptible to cracking and splitting at the maturity stage. Thus, adjustment to the combine cylinder speed and cylinder-concave clearance is very important. Usually, a low cylinder speed and wide cylinder concave clearance are recommended. Combine operators should frequently inspect harvested beans for breakage. At the harvest seed losses up to 30% have been recorded.

Uses: The oil content of castor seeds is around 48%. The importance of castor oil arises from its richness (85%) in ricinolic acid (12-hydroxy 9-octadecenoic acid)[18]. Castor oil has numerous chemical and medicinal applications and in the international market has international market has more than 700 uses. Castor oil is mainly used for lubricants, but also for polymers such as polyurethanes. It has a history of more than 50 years in the production of Polyamide-11, also known as Rilsan-11. More recently, castor oil gained interest for the production of sebacic acid (a 10 carbon atoms linear diacid), which can be used as a monomer or to produce solvents. Europe is the main world user of castor oil, presently the only commercial source of hydroxy fatty acids (HFA), consuming almost a quarter (150,000 tons per year) of the entire world production. The castor meal has high protein content of 34-36%[20], which could be high protein source for animal feeding. Castor meal has not yet used as protein supplement because it contains several toxic compounds.

Figure 5: Capsules, seeds and castor oil

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6. CRAMBE

Scientific name	Common name (s)	Family
***Crambe abyssinica* L.**	**Crambe**, Krambe, crambe d'abyssinie, Abyssinian- kale, chou Abyssinie, colewort	**Brassicaceae**

Figure 1: Crambe[2] (*Crambe abyssinica* L.)

Description of the crop: Crambe is an annual spring oilseed crop with plant height varying from 50 to 120 cm. Like camelina, crambe has a rather small cropping cycle between 85 to 105 days[1]. Usually flowering is starting 52 days from planting[1]. From the end of flowering to the maturing two weeks are required. Usually, its stems are straight when it is cultivated at high densities. Its leaves have an oval shape. The flowers are small and white with four free sepals and are arranged in racemes[1]. Although the flowers are mostly self-pollinated some cases of cross-pollination have been observed. High temperatures at flowering have a negative effect on seed set. The fruit is a capsule, initially pale green but becoming yellow with maturity, when it also becomes covered with a well-defined network of small ridges (Figure 1). The weight of 1000 seeds varies from 6 to 10 gr[3].

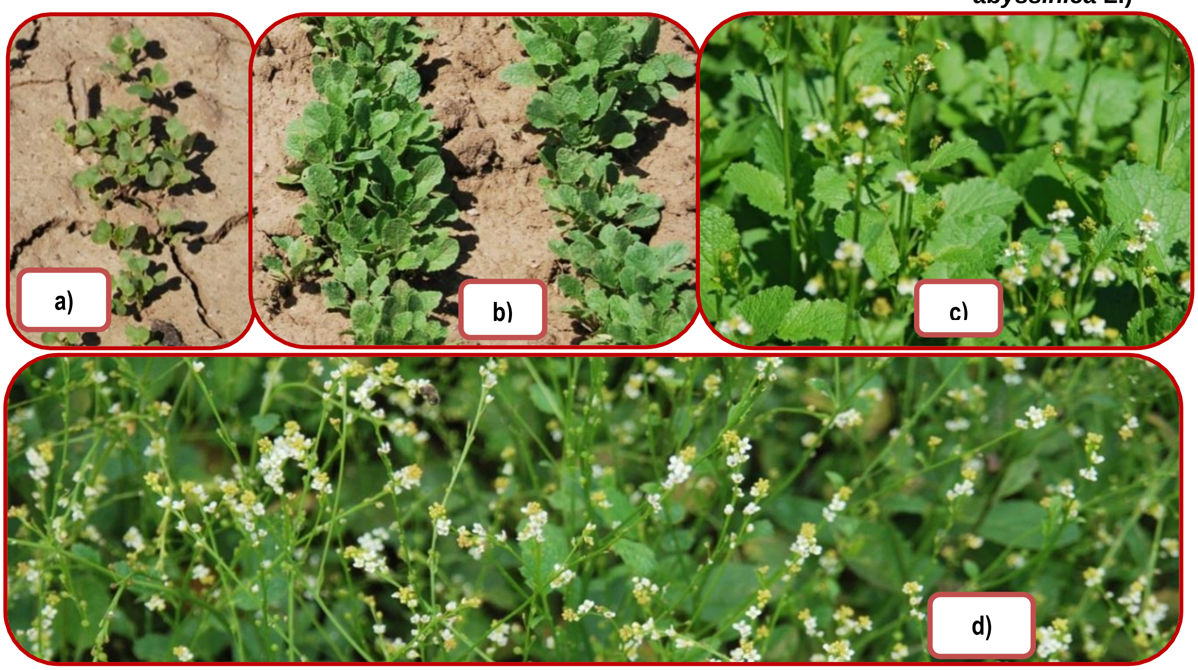

Figure 2: View of crambe at: a) emergence, b) early stages of growth, c) flowering initiation, d) full flowering (source: CRES)

Origin and research in Europe: Crambe origins from eastern Africa and domesticated in the Mediterranean region[4,5]. Besides its African origin the last century had been tested and cultivated in north Europe, former USSR, Canada and USA[6,7]. In the late 1940s crambe had been cultivated in a total area of 25.000 ha (Poland, Finland and former USSR)[8]. Breeding research works had been carried out in Europe, Canada and USA. Crambe is grown in the USA, in Pakistan, and was assessed for cultivation in China in the 2000s[9]. The crop has been included in several EU research projects and the most recently completed are: Crops2Industry[10] and EUROBIOREF[11]. Currently, crambe has been one of two under study oilseed crops in COSMOS project[12].

Varieties: Although some breeding programmes for the crop had been carried out, the number of crambe varieties available for commercial production is limited. Meyer is the only variety available in sufficient quantity for field production. Belann, Belenzian, Indy, and Prophet are other registered varieties; however, commercial seed supplies of these varieties do not exist. In EUROBIOREF project the tested variety was Galactica, while in COSMOS project additional varieties are being compared with Galactica, which are: PRi9104-71, PRi9104-101, Elst2007-2, Elst2007-3, Elst2007-7, Elst2007-8, Elst2007-9, Elst2007-16 and Nebula that had been provided by Wagenigen Research Institute.

Soil and climate preferences: Crambe can grow on a variety of soil types with pH 5.0 to 7.8[13]. The highest yields have been obtained on sandy loams, similar to those regions where it is found growing naturally. Soils that are heavy clays, sandy as well as soils with an impacted layer that restricts the root growth are unsuitable for crambe. The tolerance of crambe to saline soils is less than barley but greater or similar to wheat[14]. It has a tap root. Under stress conditions plants may develop long tap roots, which later become conical. A temperature range of 15-25°C is required over the main vegetative period. Crambe is well adapted to broad range of climates and adapted to marginal land areas with mild winters and hot and dry summers. It has adapted to colder or drier areas and in Northern Europe and can be grown as a spring crop if sown once the risk of frost has passed. In the Mediterranean region, although it can be possibly cultivated both winter and spring crop, it is recommended the sowing to be postponed till the second part of February.

Diseases and insects: Crambe was successfully commercialized, because of its inherent ability to compete with weeds, ward off insects, and escape diseases without help from pesticides. Seedlings may be attacked by flea beetle (*Phylltrea cruciferae*). Also pollen beetle (*Meligethes aeneus*) may attack young flower buds; a yield response has been observed where bee friendly insecticides were used. Crambe has been found to be susceptible to Alternaria and sclerotinia and a well-timed fungicide application at the mid-flowering stage has had a yield response (up to 1t/ha) and may also improve oil content. Fungicide dressed seed may also beneficial. Plants are susceptible to the same range and pests and diseases as those of oilseed rape including beet cyst nematode (*Heterodera schachtii*).

Figure 3: Crambe trial ready to be harvested (source: CRES; Greece)

Soil preparation and sowing: The seedbed for crambe should be firm in order to place seed at a uniform and shallow depth. Seedlings are easily damaged by drifting soil. Seed should be sown 1.5-2.5 cm deep, but up to 4 cm is acceptable in loose soil, or to ensure the seed is sown into moist soil. A seed bed temperature around 10°C is preferable at sowing. At least 100 seeds per m^2 should be seeded (15 kg seeds per ha) in order to achieve density of 75 plants per m^2. Crambe seeds should be sown at a rate of 10-25 kg/ha on a well-prepared, fine and firm seedbed, no deeper than 2 cm[15] In COSMOS project two densities are being compared 125 and 250 seeds per m^2 with narrow rows (12.5 and 25 cm, respectively). In the same project different sowing densities have been tested.

Water and fertilization needs: Although its drought resistance strongly depends on the cultivated variety, crambe can be considered as drought tolerant crop. Crambe has similar fertilizer requirements to other spring oilseed crops. The best seed yields had been achieved when 150kg/N had been applied.

Seed Yields: Crambe seed yields vary widely between 1 and 5 t seeds/ha under varying environmental situations and countries. In Brazil, a production of 1-1.5 t/ha it has been reported[14]. In COSMOS project the mean seed yields were 2.3 t/ha (varied from 0.6 to 3.1t/ha). It oil content vary from 36-43%[15]. In dehulled seeds the oil content could be up to 54%, while it is quite lower (25-33%) in non dehulled[15]**.** The content of erucic acid on the seed oils varies from 55 to 60%. On a dry basis, whole crambe seed contained 33.9% oil, 25.2% protein, and 12.3% crude fiber. Crambe meats were high in oil 47.6% and protein 31.6% and low in crude fiber at 5.0%. Crambe hulls were low in oil 1.2% and protein 8.8% and high in crude fiber 42.6%.

Harvesting and storage: Crambe can be harvested with unmodified combines and is usually direct-combined standing but can be swathed. Timely harvest is important to avoid high shattering losses. Crambe is physiologically mature when 50 percent of the seeds have turned brown. At maturity, the appearance of the plant may vary from leaves turning yellow and dropping to the plant (stems and leaves) remaining green. Usually, the crop is ready to be harvested when: a) the majority of leaves have been fallen, b) the upper part of the stem is yellow and c) when at least 75 per cent of the capsules have turned yellow (Figure 3). This is usually some 90-100 days after planting.

Figure 4: View of crambe trial in Poland (Source: COSMOS project; UMW)

Uses: Initially crambe oil gained attention due to high percentage in erucic acid[16] (higher than rapeseed) which had significant implications for industrial uses, specifically the plastics industry. Crambe oil withstands high temperatures and remains liquid at low temperatures make it a quality lubricant and transfer oil. Because it is a very effective lubricant and much more biodegradable than mineral oils, this oil may be used alone or as additives for the textile, steel and shipping industries. Crambe appears to be a promising crop because of the many possible uses of its seed (pharmaceuticals, detergents, cosmetic, ceramides, nylon and perfumes etc.). Crambe (and camelina) has been selected by COSMOS project as oilseed sources medium-chain fatty acids (MCFA, C10–C14) (Figure X). In Europe, currently, these fatty acids are obtained by the imported coconut oil and palm kernel. These FA are used by the oleochemical industry for the production of surfactants and detergents, lubricants, plasticisers and other products. Not only are the prices for these FA higher than those for the more common LCFA such as palmitic, stearic and oleic acid, but their prices are also much more volatile. Crambe seeds are crushed to extract oil. After pressing or extracting the oil, pressed cake or extracted oil meal are obtained, which may be useful as a feedstuff for cattle, and to a very little extent for pigs[16]**.**

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7. ETHIOPEAN MUSTARD

Scientific name	Common name (s)	Family
***Brassica carinata* A. Braun**	**Ethiopian mustard**, Ethiopian rape, Abyssinian mustard	**Brassicaceae**

Figure 1: ***Brassica carinata*** **A. Braun**[2]

Description of the crop: Ethiopian mustard is closely related to rapeseed (*Brassica napus* L.). The plant can be up to 120 cm height. It has a deep root system. It is a tall, leafy plant, well adapted in the Mediterranean climate[1]. It can be grown either as winter or spring annual crop. The stems are reddish-green, often profusely branched with lateral buds. Leaves are alternate, non-heading with long petioles. Flowers are usually light yellow about 1.5 cm across, on short pedicels on an extended raceme (Figure 3). Flowers are regular with four free sepals in one series and two sets of stamens. The fruit is a silique up to 5 cm long. The seeds are small but bigger compared to Brassica napus (Figure 2). The weight of 1000 seeds is approximately 3.5 grams.

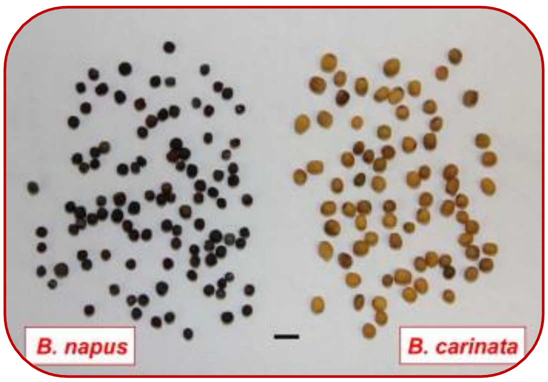

Figure 2: Comparison[3] between the seeds of B. napus and B. carinata

Origin and research in Europe: It is originated from Ethiopia. It is cultivated as oilseed crop in Ethiopia, while in southern Africa as well as in West and Central Africa it is grown as leafy vegetable. *Brassica carinata* is an amphidiploid with one genome from *Brassica nigra* (L.) Koch and the other from *Brassica oleracea* L. Several studies have pointed out its high seed yields, its ability to adapt in arid and semi-arid conditions, its tolerance to abiotic and biotic stress and thus have been proposed it as an alternative oilseed crop to *Brassica napus* for the Mediterranean region[4,5,6]. Ethiopian mustard has been included in a few EU research projects: a) FAIR CT 96 1946 – "Brassica carinata: The outset of a new crop for biomass and industrial non-food applications"[7], b) ICON project[8], c) 4FCROPS[9] and d) Crops2Industry[10]. In the first a number of *Brassica carinata* lines have been tested in the Mediterranean region (1997-2000) under different cultivation practices (sowing dates, sowing densities, and fertilization and irrigation rates) on both experimental and demo trials (Figure 3).

Figure 3: Flowers of Brassica carinata

Varieties: In Africa some breeding work has been done and several selections have been done in Tanzania, Zambia and Zimbabwe. The selection criteria were: leaf size, late bolting, reduced susceptibility to major diseases and pests, and high yield. Well-known cultivars are: 'White Figiri', 'Purple Figiri', 'Lushoo', 'Mbeya Green' and the large-leaved 'Lambo' from Tanzania, 'RRS-V' from Zimbabwe, 'Chibanga' and 'NIRS-2' from Zambia. 'TAMU Tex Sel' is a vegetable cultivar released in Texas (USA). Additional breeding works have been carried in Canada, India and Italy for the crop as oilseed. The major selection criteria were: the low content in erucic acid and glucosinolate and the high seed yield. Working selections on the crop are available in the Netherlands, Ethiopia, Tanzania, Zambia and Zimbabwe. There is substantial variation in flowering time and oil content among Ethiopian germplasm including early maturing and high oil yielding lines (up to 42% oil content)[11].

Soil and climate preferences: Ethiopian mustard it is well adapted to the temperate climatic zones of Europe. The crop is characterized by high tolerance to heat and drought and saline conditions[12, 13] but has not resistant to frost. In the Mediterranean region the crop can be grown both as winter and spring crop, while in central and north Europe should be grown as spring crop. The crop is suited to a wide range of soils and pH should be 5.5 – 8.0. The crop is sensitive to salt and the seeds may not germinate in soils with an above average salinity level. It is not tolerant to waterlogging.

Diseases and insects: It is sensitive to turnip mosaic virus (TuMV) and especially the leaf crop is vulnerable. TuMV is transmitted by a range of aphids, of which the cabbage aphid (*Brevicoryne brassicae*) and the green peach aphid (*Myzus persicae*) are the most important. The crop is susceptible to black rot (*Xanthomonas campestris*), and black spot (*Alternaria brassicicola*), and to damping off and seedling root rot (*Rhizoctonia solani*). The best disease control is the proper management rather than a spraying regime with agro-chemicals.

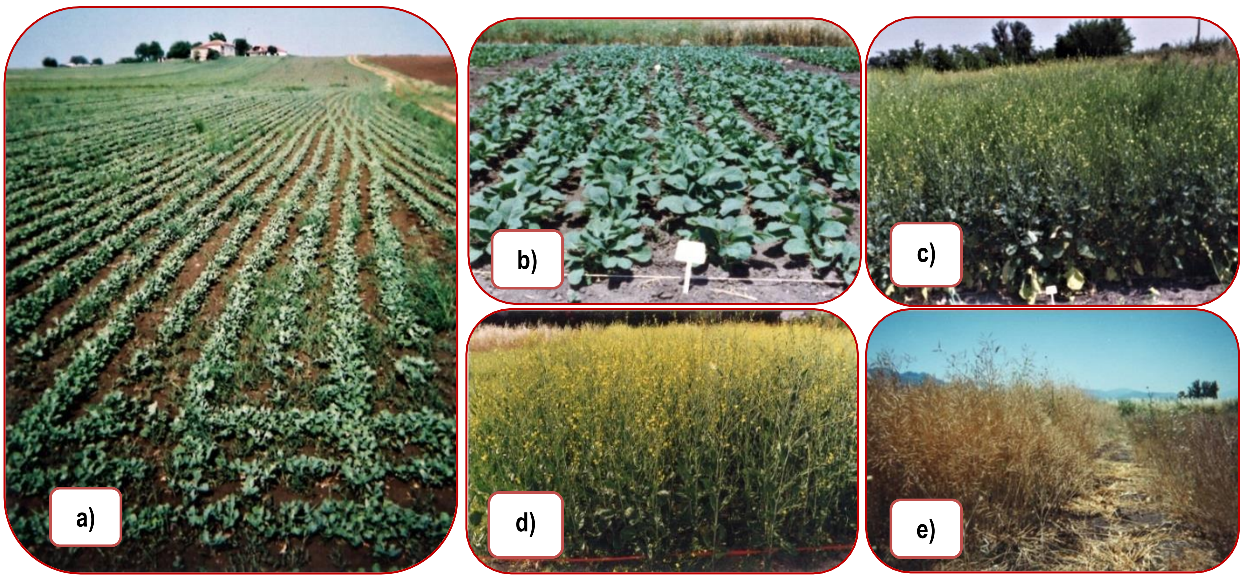

Figure 4: View of Ethiopian mustard from emergence to the harvesting time (source: CRES; Greece)[7]

Soil preparation and sowing: The soil preparation and sowing is quite similar to *Brassica napus*. For a good establishment a plant rate of 200 seeds per m^2 is recommended (8 kg seeds per ha). The sowing depth should be 1-2 cm and the distances between the rows should be 30 cm. Sowing date has been found to have a much larger effect on yield than seed rates and, where environments allow, an early autumn sowing is likely to achieve best results.

Water and fertilization needs: Ethiopian mustard responds well to organic manure of up to 20 t/ha. Most farmers find it easier to incorporate chemical fertilizers in the plant beds at the rate of about 100 kg N and 30 kg P. Higher levels of nitrogen will increase proteins and enhance leaf production, whereas more phosphorous will enhance the seed production potential.

Seed Yields: The average yields have ranged from 2t/ha up to 3t/ha in Canada. In the Greek trials (FAIR CT96 1946 project[7]) the seed yields of the compared lines came up to 1.5 t/ha. In general the oil content is 40%.

Harvesting and storage: Harvest is a critical operation and losses can be heavy due to the small seeds and because the growth habit prevents all seeds in a crop maturing at the same time. Furthermore, early harvesting can reduce seed quality and late harvesting can enhance pod shuttering. The moisture content of *Brassica carinata* at harvest time of the seed must be around 7-9% and it's recommended for safe storage of rapeseed to be dried to less than 9%.

Uses: Ethiopian mustard is usually cultivated for its oil that is rich in erucic and linoleic acids and well-indicated for biofuels. Most of the literature on the energy uses of Ethiopian mustard focuses on the production of biodiesel[I5,14] and bioethanol[15]. The oil profile of zero erucic-acid Ethiopian mustard consists of 33% oleic, 37% linoleic and 21% linolenic acid[16] compared to 61% oleic, 21% linoleic and 11% linolenic acid in *Brassica napus*[17]. The oil finds wide application in the production of water repellents, waxes, polyesters and lubricants. Seed cake that remaining after oil extraction can be used as fertilizer or feed stuff. It is also used as a green fodder crop, green manure and as a cover crop. Interest in this species for industrial uses has been increasing thanks to the particular acid composition of its extracted oil. Outside Africa, especially in western and southern Asia, it is occasionally grown as an oilseed crop or for mustard. The seeds are crushed and the oil is used for cooking and in the mustard industry. The oil has limitations for cooking because of high contents of glucosinolates and erucic acid. In Ethiopia it is used for oiling the baking plates of earthenware 'injera' stoves. It is also used for illumination. The seed is used in folk medicine to treat stomach-ache. People in Ethiopia use the sharp-tasting seeds as a spice to flavour raw meat.

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8. FLAX (Linseed / Fiber flax)

Scientific name	Common name (s)	Family
***Linum usitatissimum* L.**	**Linseed, flax**	**Linaceae**

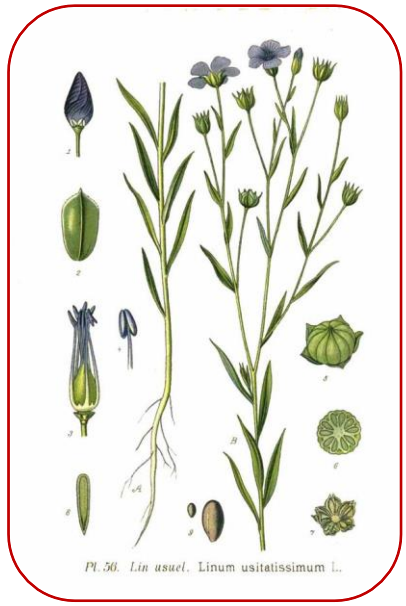

Figure 1: *Linum usitatissimum* L. [2]

Description of the crop: Flax is an annual crop cultivated either for its seeds or its fibre stems. The stems of the fiber flax are higher compared to linseed (80-150 cm vs 45-80 cm) and less branched[1]. In both types the flowers are produced on the top of the stems (Figure 1). Five ephemeral petals are internal and alternate with the sepals. The color of the petals in the commercial varieties is either blue or white, while more colors can be found (violet, purple, or pink). The fruit is a capsule, 8-15 mm long and 10-12 mm wide, contains 10 seeds. The seeds are smooth, small light and vary in color from dark to yellow. The weight of 1000 seeds is 4-6 gr.

Origin and area of its cultivation in Europe: Flax is one of the oldest known crops for the temperate climate countries cultivated either for its cellulose-rich fibers (fiber flax) or its seeds rich in polyunsaturated fatty acids (seed flax). Its origin is uncertain. According to Figure some native species of flax have been recorded in Europe, mainly in Spain. Both flax types (fiber and linseed) are being commercially grown in Europe. The main European producers for fiber flax were: France (67,760 ha), Belarus (63,200 ha) and Belgium (11,500 ha) and for linseed were: France (77,292 ha) and UK (36,000 ha)[3].

Varieties: A total number of 160 flax varieties have been registered In the European catalogue, equally divided to fiber flax and linseed[4]. The main breeding targets for flax are to develop varieties with increased resistant to biological stresses in the environment (like diseases), increased resistant to abiotic stresses like extreme temperatures, moisture and saline-alkaline soil[5,6,7] and increased yields (fibre and/or seed yields)[8].

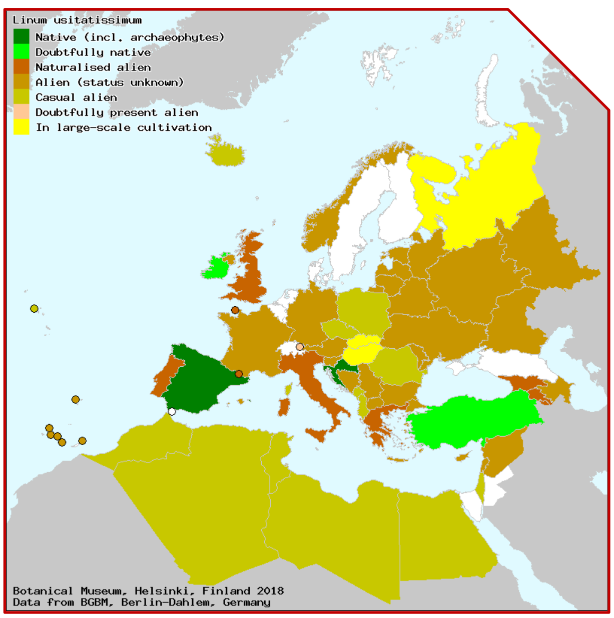

Figure X: Flax distribution in Europe[11]

Soil and climate preferences: Seed flax is grown in areas where temperatures are not too high and days are longer during the plant's growing cycle. Early and late frosts, heat damage, and drought could have detrimental effects on flaxseed quality. Fibre flax requires moderate temperatures (18-20^{0}C) and moderate cloud cover to ensure optimum yields[9]. Linseed as a crop of continental climate is more resistant to drought, sunny and warm weather conditions[10]. Flax can grow roots as deep as 1.5 meters under appropriate soil conditions. One of the agronomic advantages of including flax in crop rotations is that it lowers pest pressure on other crops and so helps reduce the amount of pesticides needed to protect subsequent crops. For optimum yields, fibre flax and linseed require fertile, medium-heavy soils, in good culture, particularly humus sandy clay soils that form no crust, with regulated water/soil/air ratio[12]. Excessive doses of calcium cause fibre breaking and its lignification; direct application of calcium should therefore be avoided. Flax can also be grown on newly cultivated post-forest, post-pasture, post-meadow (even if used for many years), and set aside soils[12,13].

Diseases: Flax suffers from various diseases, but the incidence and severity depend on climatic conditions, cultivars, crop hygiene and availability of pathogens[14,15]. Every country has problems with specific diseases of flax, but they are a few main diseases widespread over the world. The most widespread diseases of flax are: wilt (F. oxysporum), anthracnose (Colletotrichum linicola Pethybr. & Laff.), rust (M. Iini (Ehrenb.) Lev.) and pasmo (M. linicola Naumov of Septoria linocola (Speg.) Garass.)[5,16,17].

Soil preparation and sowing: Flax is sensitive to seed bed conditions, and best emergence comes from a fine tilt. Weed control in the young crop is essential. Flax seeds are very small and only have a limited reserve of nutrients. This specificity means the farmer has to prepare the soil so it promotes fast seed germination and root growth. Depending on the geographical area, winter flax is sown between mid-September and end of October, whereas spring flax is sown between the end of February and the end of March. Seed flax must be evenly sown so as to achieve optimum crop density – improving quality and yield. The sowing density should be higher for fiber flax than linseed and should be 110-140 kg and 50-60 kg seeds/ha, respectively[10,18,19]. The sowing should be done in rows 8-12 cm & 2 cm depth. The sowing time is few days after oats (soil temperature 7-8 ^{0}C).

Yields: The average commercial yields of the crop in the Eastern and Western countries are: for ginned straw yield 3.6 t/ha and 4.9 t/ha respectively, for seeds 0.7 t/ha and 0.9 t/ha, for total fibre 1.1 t/ha and 1.6 t/ha, for long fibre 0.7 t/ha and 1.1 t/ha and for short fibre 0.4 t/ha and 0.5 t/ha. These average commercial yields of fibre flax in Europe are the 50 – 70 % of the potential yielding in the countries of high level of agriculture, in the optimal climatic conditions for flax, which shows the high potential of the crop and the need to increase the flax yielding in the commercial scale.

Fertilization needs: It has been estimated that 7 t/ha contains approximately 66 kg of nitrogen (N), 32 kg of phosphorus (P_2O_5), 120 kg of potassium, (K_2O), 30 kg of calcium (CaO) and 43 kg of magnesium (MgO)[20, 21]. Fibre flax takes up relatively large amounts of potassium and, unusually, takes in more magnesium than calcium. Fibre flax requires very precise fertilization, because particular nutrients affect qualitative features of the fibre. To ensure a good yield of high quality fibre, it is recommended to provide the macronutrients in the following ratio: $N:P_2O_5:K_2O$ as 1:2:3 which should correspond to the following amounts: 20–40 kg N, 60–80 kg P_2O_5, 90–120 kgK_2O per hectare.

Figure X: Flax at several stages of growth (Source: LRCAF, Lithuania)[22]

Harvesting: Nowadays, in Europe and China it is recommended to harvest fibre flax in the green-yellow maturity phase. If fibre flax harvesting is delayed and pulled e.g. in the yellow maturity phase the fibre quality will be lowered. Linseed can be harvested later – when seeds are fully matured and linseed seed bolls give a characteristic “ring” when they are shaken. These two types of flax need different harvesting methods. The linseed straw is harvested by cutting using knife mower machine, fibre flax straw is harvested using fibre flax combine (flax harvester) or special pulling machines. In Europe, for fibre flax harvesting, self-propelling machines are applied – type ARAHY (pulling, swathing) and AECACHY (straw layer deseeding), produced by DEPOORTERE Belgium. Another fibre flax harvesting machine producer is DEHONDT France[3,23].

Harvesting can be a major problem with linseed in particular when the crop is late incompletely desiccated or lodged. Lodging can be serious in linseed but crops often recover if lodging occurs early in the season. Late lodging severely impedes harvest, with very little bulk in the crop to support itself and allow room for the combine, and great care must be very well desiccated at harvest to avoid wrapping in the combine, and great care must be taken to ensure thorough penetration of the desiccant into the crop. Winter flax is harvested around 20 July (in the North of France / early July for the South), a month before spring flax harvest. When seeds turn dark brown, they are harvested by cutting and threshing. Producing high quality seeds requires that producers pay careful attention and invest time and effort in harvesting.

Figure X: Harvesting of linseed on the left[24] and of fiber flax on the right[22]

Uses: It is an annual crop cultivated for its fiber stems (cellulose-rich fibers) and its oil seeds (35-50% oil which is rich in polyunsaturated fatty acids). Actually, whole plant exploitation is possible, which justifies the name given to it by Linnaeus: L. usitatissimum, meaning “useful flax”. There is a wide range of possible applications of flax. The long fibres are used in the textile industry and medicine (wound dressing)[25] and the short fibres in paper production, isolation materials, biodegradable packaging material and biocomposite production. The wooden shives released during flax scutching can serve as an energy source and valuable compounds with antibacterial activity. Flax seeds also may have many important applications, and due to its high nutritional value, it can be used in the food, pharmaceutical and health care industries. The seedcake, which is rich in antioxidants, might be used in the pharmaceutical and cosmetic industries. Flax fibres have many useful applications. They are flexible, lustrous and soft. Moreover, flax fibres are stronger than cotton but less elastic. They absorb humidity and are allergen-free. These properties make flax fibres useful in the textile industry but they are also used in the manufacture of car-door panels, plant pots and retaining mats.

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9. Industrial hemp

Scientific name	Common name (s)	Family
***Cannabis sativa* L.**	**Industrial hemp**	**Cannabinaceae**

Description of the crop: Hemp is an annual spring crop that traditional used to be cultivated for its fiber stems. It is a rapid growing crop that can reach a height of 4 m in 100 days. Traditionally, hemp is a dioecious species. The male plants form loose, strongly branched panicle with very low number of leaves, while the female ones produce compact panicles with lots of small leaves. In both cases the inflorescence is a panicle (Figures 1 & 3). Three main sections can be distinguished in the stems; the bark where the fibres bundles can be found, the woody core body and a hollow space in the middle of the stem (Figure 2). The leaves have a palmate shape with 5 to 11 sections depending on their location on the stems (lower on the top of the stem). The leaves fade gradually and fall off the plant as the plant matures. It has a strong tap root system, reaching 1.5-2 m deep into the soil. The main root mass is located 20-40 cm soil depth. Hemp seeds have a spherical-oval shape slightly flattened from both sides, gray-green with a characteristic, marble-like pattern on the shell (Figure 1).

Figure 1: Flowers (male on the left and female on the right), leaves and seeds *Cannabis sativa* L.

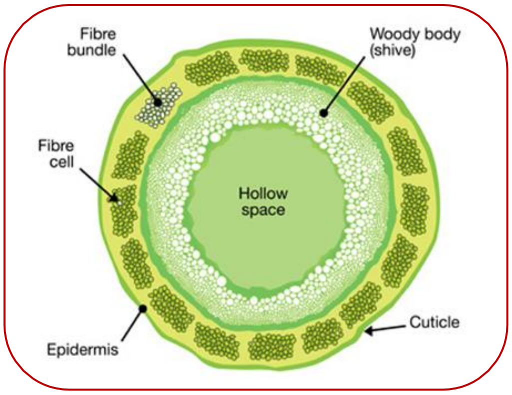

Figure 2: Parts of the hemp stem

Figure 3: Male plants on the left and female on the right.

Origin and area of its cultivation in Europe: It is originated from middle Asia from where it migrated to Eastern and Southern Asia. It has been first grown in China (5000 years ago) and from there it was spread to the whole world[1]. Hemp is considered as an old-new crop. The last years an increasing interest for industrial hemp has been recorded worldwide (www.eiha.org). In particular in Europe the area of its cultivation from 14,000 ha in 2012 came up to 42500 in 2017. Although, the main producer in Europe is still France an increasing growing area has been recorded in Italy, Italy, Netherlands, Lithuania, Estonia, Ukraine, Romania and Germany (www.eiha.org). Research on industrial hemp has been carried out in several EU research projects namely HEMPSYS, 4FCROPS (www.cres.gr/4crops), Crops2Industry (www.crops2industry.eu), MULTIHEMP (www.multihemp.eu) and FIBRA (www.fibrafp7.net). Currently, the crop is being included in GRACE (www.grace-bbi.eu) and MAGIC (www.magic-h2020.eu) projects. In the last two cases the crop is being cultivated on marginal and contaminated lands.

Varieties: Hemp is naturally dioecious crops with male and female plants. The male plants are shorter with higher fiber content[2] that mature earlier than the taller female plants that produced more in terms of seeds. Currently, a number of monoecious varieties have been selected in order the agronomic problems related to the sexual vegetative dimorphism present in dioecious varieties to be reduced. The monoecious varieties produce uniform plantations and the plants have similar maturity, height, fiber content and seed productivity and ultimately efficient mechanical harvest[4]. Currently a total number of sixty-eight varieties[3] are being registered in the European catalogue and cultivated either for fibers, for seeds or for both.

Soil and climate preferences: Hemp grows best on fertile soils with 7.1-7.6. It should not be grown on acid soils where pH is below 6.0. Hemp has no special requirements in terms of the preceding crop. It grows well after root crops grown on manure and legume crops. It can be even grown for few years on the same field. It improves the structure of the soil due to it tap root. Hemp absorbs heavy metals such as Cd, Pb, Zn, Cu, and thus contribute to the cultivation of contaminated soils. It requires a mild, temperate climate and an annual rainfall or irrigation of at least 500 to 700 mm. The hemp plant is sensitive to short day length which induces early flowering. Flowering time is a very important factor in hemp yield determination, both in terms of quantity and quality[5]. It requires long days (14-16 hours) during its vegetative phase.

Figure 4: View of hemp (Futura 75) at several stages of growth (source: CRES); a week from sowing, four weeks from sowing, vegetative phase, flowering phase and top of the stems.

Diseases: Hemp can also suffer from fungi, the diseases like Fusarium wilt, septoriosis and gray mildew are found especially in weather conditions promoting these diseases. Sometimes, especially if hemp is grown several times on the same stand, in may suffer from a parasitic plant – branched broomrape (*Orobranche ramosa* L.). Also virus diseases may sometimes attack hemp.

Soil preparation and sowing: It can be sown when the average air temperature stabilizes at 8-10°C. The sowing density is strongly depends on the end-use of the crop. Thus, for fibre production 60-70 kg seeds/ha should be applied, while for seeds production this is much smaller (10-15 kg seeds/ha). The row spacing should be 12.5-25 cm or 50-70 cm, respectively. The seeds should be sown 3-4 cm deep. When it is grown for seeds special attention should be given to weed control; especially to *Elymus* *repens* (L.) Gould. When it is grown for fibre production at high densities and narrow row spacing no special weed control is needed since the crop compete successfully the weeds. The soil bed preparation should be similar to spring cereals.

Fertilization and irrigation needs: The optimum fertilizers doses are: N: 90-120 kg/ha, P_2O_5: 70-100 kg/ha, K_2O: 150-180 kg/ha. When the crop it is grown for fibre special attention should be given on potassium and calcium (important for plant cell formation), while when growing for seeds the phosphorus availability is very critical for the seeds formation. For fibre production the NPK ratio should be 1:0.7:1.5, while for seed production should be 1:0.8:1. When hemp follows legumes less nitrogen fertilization is needed. High nitrogen fertilization can prolong the vegetative phase and the risk for lodging is increasing. It grows best when supplied with moisture throughout its growing season and especially during the first six weeks of growth. For optimum yields, 250 to 300 mm of moisture during the vegetative growing stage is required. Droughts at germination and flowering phases can seriously damage the growth and yields of the crop.

Yields: In Europe the mean yields in terms of dry stems is 7.5 t/ha and for fibres 2.5 t/ha. The seeds contain 32.5% oil, 70% is corresponding to polyunsaturated fatty acids[6].

Harvesting: Time of harvesting depends on the purpose of cultivation of hemp. When it is grown for fibre the harvesting should be done in the beginning of flowering[7]. At that time the fibre are delicate and quite strong and are appropriate to textile production. When the harvesting is being delayed the fiber yields are increasing but because the lignification[8] is also increased the fibres are not appropriate for the textiles but can be used for pulp production. When it is grown for seeds or fibres and seeds the crop should be harvesting at harvested at full maturity phase, when seeds in the middle part of panicle are mature. At that time the fibres can be used for non-textile applications (insulation mats, etc.). In Figure 5 the harvesting of hemp for both seeds and fibres in Romania is presented.

Figure 5: View of harvesting in Romania (source: CREA)

Uses: Although industrial hemp is considered as fiber crop, high-value bio-products can be produced from all plant parts (stems, leaves, seeds and flowers) and thus it is considered a natural biorefinery. In Figure 6 presented the current main uses of the crop per plant part. The fibres of its stem are being used for paper and pulp, insulation mats, bio-composites and textiles. The shivs (the woody part of its stem) are being used as construction material, for animal bedding, garden mulch, etc. The seeds can be consumed as food and/or feed, the seeds oil can be used either for food and feed consumption or for cosmetics and heath care products. The flowers have numerous pharmaceutical uses from THC, CBD and other cannabinoids. Finally, from its leaves are being produced pharmaceutical products, tea bags, etc.

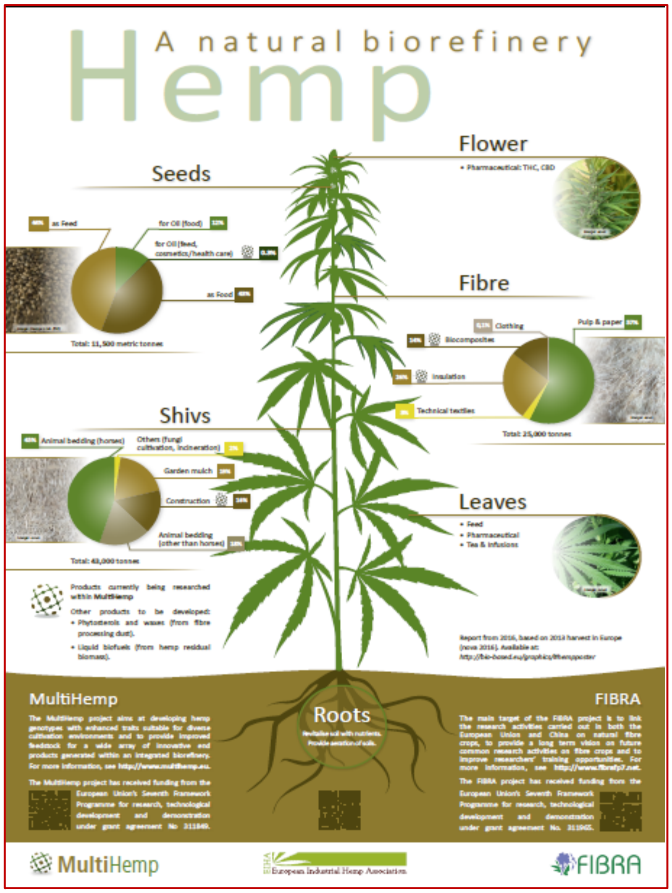

Figure 6: Industrial hemp: a natural biorefinery (poster developed by EU projects Multihemp & FIBRA)

Hemp has a very long history of medicinal use. It has been traditionally used by different cultures in treatment of various types of ailments: asthma, cystitis, diarrhea, dysentery, gonorrhea, gout, epilepsy, malaria, fevers etc. The whole plant is considered to be anodyne, anti-inflammatory, antispasmodic, cholagogue, diuretic, emollient, hypnotic, hypotensive, laxative, narcotic, ophthalmic and sedative. Today, hemp is used for relieving side effects of cancer treatments, such as nausea and vomiting. Since it increases the desire for food, it is also used in treatment of anorexia nervosa. It can be used as food component and for production of technical products such as: detergents, varnishes, paints, lamp fuel or an emulsifying medium in pharmacy. Hempseed oil is described as desired raw material for production of so called greasy soap (grey soap). This soap is called also green soap in many counties from the colour given to it by chlorophyll contained in the soap. It is worth mentioning that hemp essential oil, a different substance extracted from hemp is used for a medium repelling parasites found e. g. on horse skin. It also displays properties similar to many other essential oils – bacteriostatic, repellent to pests.

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10. Kenaf

Scientific name	Common name (s)	Family
***Hibiscus cannabunus* L.**	**mesta, teal, ambari hemp and rama**	**Malvaceae**

Figure 1: *Hibiscus cannabinus* L.

Description of the crop: Kenaf is an annual spring crop that is cultivated for its fibrous stem. Kenaf stems are generally round with thorns that ranging from quite tiny to large such as on a black berry bush depending on variety. Stem colour varies from pure green to deep burgundy. Kenaf stems have a thin bark over a woody core, surrounded by a leaft tuft[1]. Kenaf stems contain two major fiber types, the one contains long fibers situated in the cortical layer, and the other one contains short fibers located in the ligneous zone. The flowers are large (7.5 to 10 cm) with five petals. The flower colour ranges from light cream to dark purple. The seed develops in five-lobular capsule (Figures 1 & 2). The capsules of cultivated varieties are generally indehiscent and remain intact for several weeks after reaching maturity. The seed is small (1.5-3.3 gr/100 seeds), black in color and subreniform in shape (Figure 2).

Origin and area of its cultivation in Europe: The existence of semi-wild kenaf in Africa (Kenya and Tanzania) might be an indication of the origin of the cultivated kenaf from this continent[2]. In Europe it has been investigated in a number of EU research projects namely BIOKENAF[3], 4FCROPS[4], Crops2Industry[5], FIBRA[6]. The BIOKENAF project offered an integrated approach for kenaf covering the whole production chain (production, harvesting and storage) testing the suitability of the crop for industrial products (high added value) and energy. This integrated approach was carried out taking into consideration the environmental and the economic aspects of the crop and through a market feasibility study was led to the production of industrial bio-products and biofuels with respect to security of supply and the sustainable land management. Currently, kenaf is being investigated in BeCool[7] project. In figure 3 presented the crop at several stages of growth in field trials contacted in Greece.

Varieties: Kenaf varieties according to their reaction to flowering can be grouped to early and late ones. The flowering in the late varieties is closely related to the day length (the flowering starting when the day length is lower than 12½ hours). More than 240 varieties have been produced in USA but only few are commercially grown (Tainung 1, Tainung 2, Everglades 41, Everglades 71, Dowling, Gregg, SF 459, and Whitten). Recently, a number of high yielding varieties have been developed in China (H328, H368, etc.). These varieties have been tested in the Mediterranean region and their productivity was higher compared to varieties imported from USA.

Figure 2: View of the plant's parts (stems, flowers, roots, leaves and seeds)

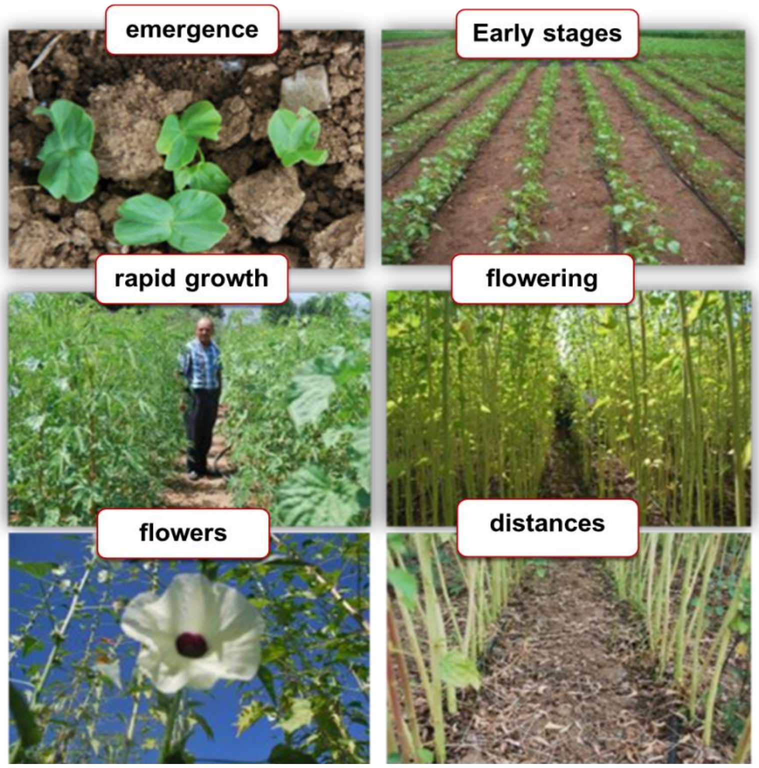

Figure 3: View of kenaf plantation at several stages of growth (source: CRES)

Soil and climate preferences: It can be grown in a wide range of climates and soil. In general, it can be grown up to 45^0N (South Europe). Its yields are higher in areas with high temperatures, long growing seasons and abundant soil moisture. It is quite sensitive to low temperatures and grows slowly when temperatures are below 10°C. Although, it is adapted to a wide range of soil types, it performs best on the heavier, well drained, fertile soils. Areas with drainage problems should be avoided.

Diseases: Kenaf has high susceptibility to root knot nematodes caused by *Meloidogyne incognita*, *Meloidogyne javanica* and *Meloidogyne arenaria*. Nematodes are multicellular, microscopic, worm-like animals that feed mainly on plant root systems. Leaves on plants infested with nematodes and became yellow and fall down. The infested plants are stunted and in case of a heavy infestation the plant may eventually die. The problem is particularly severe in light, sandy soils (Figure 4). The problems from nematodes could be managed by a combination of crop rotation and chemical control. Another approach is the development of nematode resistant varieties. The variety SF 459 it is reported as nematode resistant. It is reported[8,9] that the rotation kenaf/soybean was successful in terms of yields but did not reduce stunt nematode populations.

Soil preparation and sowing: Kenaf seeds are relatively small and require good seed-soil contact for germination. Therefore, a fine, firm, well-prepared seedbed is necessary. The ground temperature should be 15^0C at least as warmer temperatures result in an increase in growth rate. Under favorable soil conditions kenaf seeds emerge after two to four days. In South Mediterranean countries, kenaf can be planted in the spring once the soil has warmed to 13°C and there is no threat of frost (April to May). The sowing depth should be up to 2.5 cm. Kenaf is self-thinning crop and reduces its population during the growing season. When kenaf is cultivated at high plant populations, range from 300,000 to 500,000 plants/ha, it is required a total quantity of 10-15 kg seed/ha, while when it cultivated to achieve final plant populations of 185,000 to 370,000 plants/ha a quantity of about 8 to 12 kg/ha seed is needed. In warm climates kenaf emerges and grows so rapidly that it competes with weeds effectively. In cooler climates and with earlier planting dates, cultivar and/or chemical weed control measures are more

Figure 4: Roots that have been affected by nematodes.

important. One weed species, which is especially competitive with kenaf, is velvetleaf, a relative of kenaf. At the seedling stage, velvetleaf and kenaf are very similar in appearance and rate of growth. Fields with high populations of this weed are not recommended for kenaf production.

Yields: In the view of this project (EUROKENAF) demonstrative fields had carried out in all the Mediterranean countries. The achieved yields affected by the sowing date, the site of the trial, the water availability and the soil fertility. Dry stem yields 8 to 18 t/ha had been recorded in Greece, 12 to 17 t/ha in Italy, and 13 to 24 t/ha in Spain.

Fertilization and irrigation needs: Kenaf, unlike traditional agricultural crops that are grown for their seed, is grown mainly for its fiber stems and recently it is grown for both (stems and seeds). When the crop is harvested after the first killing frost the stems are defoliated. It has been estimated that the leaves drop returns significant quantities of nitrogen (as high as 4.0% by weight[8]) calcium, magnesium, phosphate and potassium back to the soil where the stalks that remain prevent them from blooming away. 500-625mm of rainfall over a period of 5-6 months is essential for a successful production of kenaf fibre. A well-distributed rainfall of about 125 mm[10] for each month during the growing season leads to optimum yield.

Harvesting: According to the end use of the crop, kenaf can be harvested as green or dry material. The green material is harvested during flowering (for high fiber quality), while the dry material during winter, when the death plans are still upright in the field, free of leaves, and with stems degraded by atmospheric and biologic processes. The harvesters that can be used are: a) sugarcane type, b) jute/reed type, c) forage type combined with baling equipment and d) combined harvesting when stems and seeds should be harvested at the same time.

In BIOKENAF project harvesting trials had been carried in winter when the harvesting material had lowest possible moisture content (Figure 4) and it was used a maize harvester (JAGUAR 870 -CLAAS). The moisture content of the chopping material was 23%. The chopped material had been delivered to KEFITALIA Company, where it was separated to bark and core. The bark material it was used for insulation mats production(Figure 5).

Figure 5: Harvesting trials in northern Italy (source: CETA; Biokenaf project)

Uses: Kenaf is a traditional third world crop that is poised to be introduced as a new annually renewable source of industrial fiber in the so-called developed economies. Kenaf like all the other important fibre crops (jute, roselle, hemp, flax, ramie, etc.) can be pulped to make a range of paper and pulps comparable in quality to those produced from wood. With forests dwindling and the virgin wood become more expensive and the increasing demand for paper products it is understood why the non-wood fibre crops such as kenaf could are so important[11]. Kenaf in a period of six months reach a plant height of 3 to 4 m and its production is two to three times higher (per ha and per year) than the southern pine forests[12].

Figure 6: Insulation mats produced by KEFITALIA (BIOKENAF project)

Although the importance of the crop is mainly referring to paper pulp production, kenaf is being characterized as a multi-purpose crop because it has a number of additional industrial applications. Thus kenaf fibers (either derived from the bark or the core of the plant stem) can be an excellent source for several other uses such as for fabrics, building materials (particleboards, low-density panels, wall paper backing, furniture underlays etc.), bedding material, poultry and/or cat litter, oil absorbent, etc[13]. Additionally, the whole plant has high protein and good digestibility and may be pelletized[14]. Its seeds contain 20-25% oil which is rich in polyunsaturated fatty acids. Preliminary studies showed that kenaf oilseed can cure many health disorders such as blood pressure, cholesterol balance and some types of cancer. The crude protein in kenaf seed meal is 44.5 %.

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11. NETTLE

Scientific name	Common name (s)	Family
Urtica dioica L.	Common nettle, stinging nettle, nettle leaf	Urticaceae

Figure 1: *Utrica dioica* L.

Description of the crop: Nettle is a perennial herbaceous crop with lifetime 10 to 15 years. It is dioecious crop, male and female flowers can be found on separate plants. The height of the stems varied from 1.2 to 1.8 m. Its stems are unbranched. Belowground the nettle plants produce branched rhizomes with long internodes and secondary roots forming on the nodes. Leaves are elongated and are arranged opposite on the stem, crosswise. The surface of the stems and the leaves are covered with stinging hair containing a fluid which causes blistering when entering the skin[1] (Figure 1). The nettle fruit is a non-breaking nut. The nut contains only one seed. The nut is oval, with narrowing tip. Having reached maturity, the fruit falls off in whole from the plant. The seeds are too small.

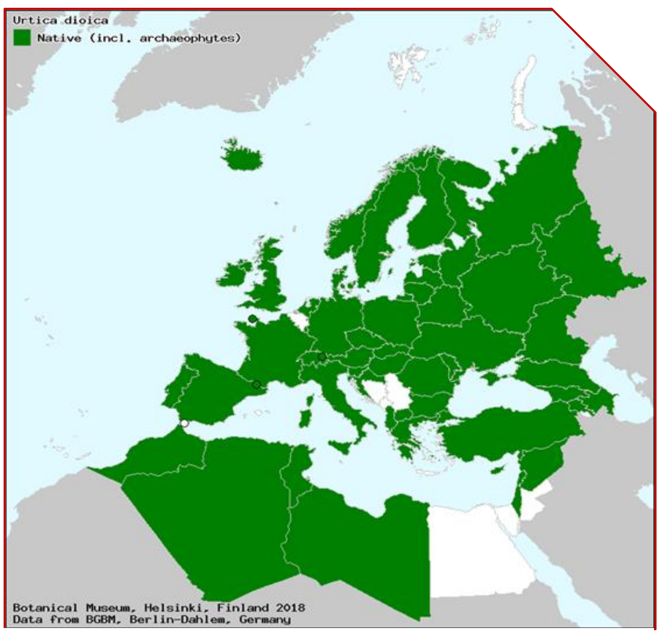

Figure 2: Distribution of *Urtica dioica* L. is Europe and North Africa

Origin and area of its cultivation: The stinging nettle grows in the wild conditions in Europe (Figure 2), Asia, North America, generally is growing generally almost everywhere except the tropical zones. Although, nettle is considered as a weed in intensive agriculture[2], it is currently considered as a biomass source for several added value products by exploiting all the parts of the plant (stem, leaves, roots and seeds). A total area of 500 ha of nettle had been established in Germany and Austria as fibre source. The last two decades several national projects had been carried out in Europe (Italy, Germany, Lithuania, Finland and UK) as well as one EU funded project (FAIR-CT98-9615: NETTLE reintroduction of stinging nettle cultivation as a sustainable raw material for the production of fibre and cellulose; https://cordis.europa.eu/project/rcn/55293_en.html; 1999-2001). Most of the projects explored the use of stinging nettle as an alternative herbaceous fibre and for related-cellulose applications[3].

Varieties: Nettle is practically not grown commercially in Europe; it is usually considered a weed, although the nettle genus contains approximately 600 annual and perennial species yielding fibre. In 2001, the Austrian Institute for Agrobiotechnology in Tulln tried to continue the research activities that had been done in Germany and selected around 30 clones with improved fibre content and spinning quality.

Soil and climate preferences: Nettle has moderate climatic requirements and can be grown in most European countries[4]. It survives winter with its remarkable underground rhizomes. It prefers to grow on loose soil with organic matter rich in nitrogen and high phosphate levels[1] for rapid growth. Although, it requires moist soil, it cannot tolerate long flooding. It thrives best in neutral soil but can be cultivated on soils with pH 5.6–7.6.

Diseases, insects and weed control: Nettle is considered as a crop free of diseases and pests. Weed control is quite important, especially in the establishment year. It is recommended to use widely spaced rows and mechanical weed control. In interim periods (after harvest and till the next regrowth), the main weed problems have been caused by monocotyledonous weeds.

Soil preparation and sowing: Stinging nettle can be propagated either by seed or by vegetative propagation (rhizomes or cuttings)[7]. The planting density is strongly depends on the establishment way (seeds, rhizomes, seedlings) and on the purpose of its cultivation (fibres, leaves, roots). When it is established by seeds a high degree of heterogeneity is recorded (especially at the establishment year) that results in lower content and quality of fibre. Currently, the most effective establishment method is by seedlings in spring and the distances between the rows should be 60 to 75 cm and within the rows 50 to 60 cm[8,9,10].When the crop is established by seeds 1000 seeds/m^2 is needed and the row spacing should be 20 cm. The seeds are very small and thus the sowing depth should be less than 1 cm.

Figure 3: View of nettle; a) early stages of growth at the establishment year, b) flowering in the 1st year, c) harvesting time in the 2nd year, d) regrowth in the beginning of the 3rd year (source: CRES)

Water and fertilization needs: Nettle is considered as a crop with low input requirements. The fertilization that should be applied is 60–80 kg N/ha, 150–180 kgK_2O/ha and 40–50 kg P_2O_5/ha[6]. There is lack of knowledge on the water needs of nettle. It has been found that when the crop receives 50mm in summer from the rainfalls can survive without irrigation.

Yields: Field trials have been done in some EU countries namely Italy, Austria, Lithuania, and Germany. The dry stem yields than can be anticipated up to 15 t/ha. The fibre content of the dry stems varies from 11 to 16%. The dry stem yields reached its maximum yields in the 2nd or the 3rd year. The upper stalk part of nettle has higher percentage of fibre respect compared to the woody core. The yields of fibre are affected by the clone used, the plant density and the harvesting time.

Figure 4: View of nettle field in Italy (source: CNR-IBIMET)

Harvesting and storage: The harvesting time is strongly depends on the end use. For fiber production it is proposed to be harvested between late summer and early autumn that corresponding to the flowering period of the crop. After harvesting all leaves are removed from the stem and the strait and long stems are collecting for fibre production. It can be harvested mechanically by using hemp processing – scutching drums and short fibre processing units. The length of nettle technical fibre is 80-120 cm. The structure of the stem is similar to ramie.

Figure 5: Mechanical harvest of nettle (source: CNR-IBIMET)

After harvest stems should be dried up to 15% moisture content. Nettle fibre can be extracted from dry stems by decortication method. Technical fibre is soft, silky, resilient and grey-white. Its length is below 80 cm. As shortening of fibre is relatively easy during retting or chemical degumming, the best form for further processing is cottonized fibre. Fibre is extracted by the biological method (stem retting in flowing or stagnant water). Retting in flowing water produces bright, soft and glossy fibre while retting in stagnant water – dark gray fibre. Content of formic acid makes the retting process more difficult as it is an inhibitor of retting.

Uses: Value added products can be produced by nettle stems, leaves and roots. Nettle can be used in textile (ropes, textile, paper & pulp, biocomposites, etc.), in medicine (anemia, rheumatism, gout, eczema, diuretic, hypoglycemia, hypotension, benign prostatic, hyperplasia, cardiovascular problems, arthritis, allergic rhinitis, antioxidant, antimicrobial, antifungal, antiviral, antiulcer), for cosmetics (shampoo, soaps, skin lotions), food (salads, pies, tea), forage crop (poultry, cattle, horses and pigs for enhancing yolk yellowness), animal housing (bedding material) and bioenergy.

Nettle fibres are used for sails, tents, sacks also for nets, cords, flour sieves, etc. The yarns are woven, crocheted, and knitted into many different types of items – everything from clothing and ceremonial accessories to fishing nets and bags. The fibers are processed and spun by hand. The resulting yarn has a natural and rustic appearance. These yarns have a texture similar to natural linen and like linen will soften with wear. The advantages of nettle fibre are: its low weight, strength, low water sorption and resistance to rotting. Today, nettle fibre is used as a component to produce blended yarn with cotton, bamboo, cotton, linen and other natural fibres. Its leaves are used for cosmetics (creams, masks, and tonic). Medicines can be produced from its leaves, roots and seeds that can cure urine system, can improve the digestion, as supplement in curing diabetes as well as used as treatment of skin and hair. From its leaves and stems can be produced green permanent dye. Nettle is also used in shampoo to control dandruff and is said to make hair more glossy, which is why some farmers include a handful of nettles with cattle feed.

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12. PENNYCRESS

Scientific name	Common name (s)	Family
***Thlaspi arvense* L.**	**Pennycress**	**Brassicaceae**

Figure 1: *Thlaspi arvense* L.

Description of the crop: Pennycress is an annual winter annual. Only recently it was attracted attention as an oilseed crop. In the recent past it was considered as a weed. It is one of the most easily recognized members of the Brassicaceae family because of its large and plentiful fruits which have the characteristic cabbage-like flavour when chewed (Figure 1). In spring the basal leaves grow in a rosette, oblong, or narrowly obovate and they can grow to 8cm long and 2 cm broad. It can be up to 1 m high but the most common is to be 50-60 cm. The weight of 1000 seeds is less than 1 gr (around 0.85 gr).

Origin and area of its cultivation: Pennycress is native to Europe (Figure 2) and thus it grows throughout Europe, UK, northern Africa, Japan, and Siberia and throughout Canada and the U.S. Researchers has begun studying the genetics of pennycress in order to improve its potential use as a biofuel crop. The crop was investigated as a potential new source for erucic acid although was lower than crambe due to its agronomic advantages especially in light of the food versus fuel debate.

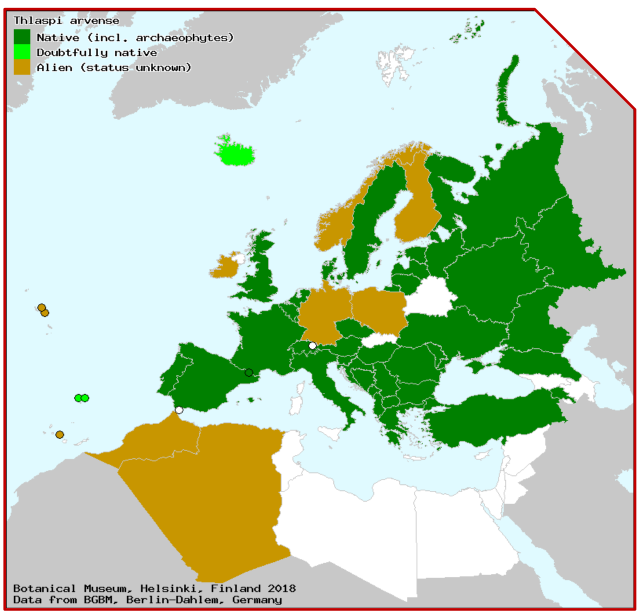

Figure 2: Pennycress distribution in Europe and North Africa[1]

Varieties: In USA the last decade a large collection of wild accessions and lines have been compered in terms of growth and seeds production. Recently, lines (Elizabeth and MN-106) that have been provided by USA are being tested in the Mediterranean region (Italy & Greece). Photos from these Mediterranean trials are presented in figure 3. Currently, in the CropSys CAP project (https://www.cropsyscap.org), pennycress and camelina have been selected for the new or improved production systems (double- and relay-crops, intercropping in corn-soybean and wheat-soybean).

Soil and climate preferences: Field pennycress can occur in all soil types, but appears to prefer moist places. It prefers to be grown on a fertile loam o clay-loam soil. It is commonly found along roadsides, in waste areas, cropland, weedy meadows or pastures, and gardens with full sun and moderate moisture, particularly on loam and clay soils. It has a very short life cycle allowing opportunities for double cropping. It has a tap root system and it is considered that can be grown on marginal lands. It characterized by wide environmental adaptability. This plant prefers disturbed areas, and its capacity to invade higher quality natural habitats is low. It is frost tolerant crop.

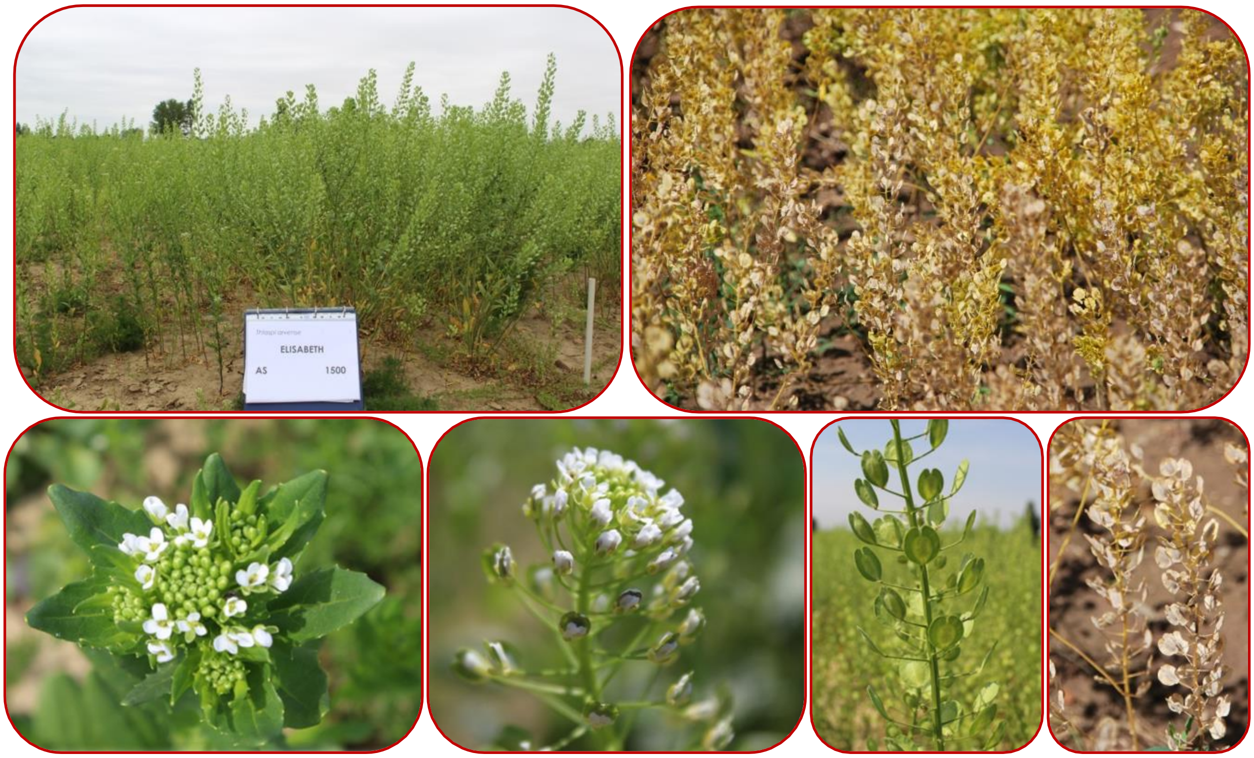

Figure 3: Pennycress at several stages of growth in Italy and Greece (Source: UNIBO-Italy & CRES-Greece)

How to grow the crop: The increasing interest on pennycress in USA[2,3,4,5] is based on its potential to be grown in parts of the corn-belt as winter crop or spring crop in between corn and soybean crops. The crop has very short growing cycle and it is ready to be harvest at the end of spring. The crop is able to be harvested easily with existing equipment and doesn't suffer the shattering issues that often plague other new crops developed from wild plants (Figure 4). The density in the pennycress fields should high. For pennycress sowing the quantity of the seeds that should be applied should be 2.5 to 5 kg/ha. Production requires few inputs. Management of field pennycress for oilseed production is very similar to that for winter small grains. Equipment needed, including a no-till drill or access to an aerial applicator, combine harvester and wagons for transportation, is similar to the needs other small-seeded grain or oilseed crops. No herbicides, insecticides, or fungicides are recommended for production. Projected nutrient removal for a crop is 22 kg/ha nitrogen, 22 kg/ha phosphorus, and 22 kg/ha potassium. These rates will change as genetics improve and yields increase.

Seed Yields: Seed yields varied from 500 to 1000 kg/ha. The oil content of the seeds is 36% and the erucic acid is 38%. The oil contains up to 38 percent erucic and 22 percent linoleic fatty acids.

Uses: Pennycress has been selected as a potential oilseed for biodiesel production[6,7,8] with high percentage on erucic acid that is not proper for human consumption. Biodiesel from field pennycress oil performs better at lower temperatures than biodiesel made from soybean oil. The oil of pennycress meets all the parameters required for biodiesel. The cloud point turns out to be better than soy-based biodiesel and has less saturates making it more oxidatively stable than soy. Following oil extraction, the remaining seed meal contains 32 to 35% protein, some fat and carbohydrate due to high amounts, of glucosinolates, cannot be used for human food or fed directly to livestock without further processing. Pyrolysis of the defatted seed meal can yield aviation fuel.

Figure 4: Harvest of pennycress in Illinois (by Peter Johnson, on the left) and in Minnesota (University of Minnesota, on the right)

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13. POPLAR

Scientific name	Common name	Family
Populus spp.	Poplar, aspen, cottonwood; native to most of the northern hemisphere.	***Salicaceae***

Description of the crop: Poplar belongs to the genus *Populus* of the Salicaceae family and it is, together with willow, the most common species in SRC plantation for bioenergy in Europe. The natural distribution of poplar extends from the tropics to the latitudinal and altitudinal limits of tree growth in the Northern hemisphere. Species of the genus *Populus* are deciduous or (rarely) semi-evergreen and divided into six sections: Abaso (Mexican poplar), Aigeiros (Cottonwoods and black poplar), Leucoides (swamp poplars), Populus (white poplars and aspens), Tacamahaca (balsam poplars), and Turanga (arid and tropical poplars).[1]

Figure 1: Poplar SRC in Europe

Origin and research in Europe: The tolerance of poplars in a wide range of soil conditions was one of the reasons for selecting and testing in the framework of *Dendromass4Europe* project (H2020) which aims the woody biomass (dendromass) production from sustainable short rotation coppices (SRC) established on marginal lands (https://www.dendromass4europe.eu/) and the development of new agricultural regional cropping systems. The *SRCplus* project (Intelligent Energy Europe) aimed the promotion of SRC in Europe for the biomass production from woody species including Poplars. Poplar plantations were also selected for funding in the past, in the framework of the European FP7, as the main objective of research and innovation projects for energy and wood products like the *STREPOW* (*Strengthening of research capacity for poplar and willow multipurpose plantation growing in Serbia*, 2008-2011), the *ENERGYPOPLAR* (KBBE, *Enhancing Poplar Traits for Energy Applications*, 2008-2011) and the *I-PAN* project (*Innovative poplar low density structural panel*, http://www.ipanproject.eu/). European projects focused on wood production from poplar plantations we also funded during early 90's like the '*Poplar network'* (FP2-JOULE 1, 1990-1992) and the '*Interdisciplinary research for poplar improvement'* (FP3-AIR, 1992-1995)

Varieties-Hybrids-Clones: Poplars are fast-growing trees with more than a dozen cultivars and hybrids including Aspen trees. Poplars are medium to large trees with straight trunks and an upright growth habit. Many cultivars reach up to 30 meters in height at maturity with foliage that is roughly spade or maple leaf-shaped with lightly to deeply toothed margins. The poplar species is tolerant of a wide range of soil conditions, but there are a few parameters that must be heeded to keep the trees healthy and problem free. Many poplar species are native to Eurasia (). The main clones that have been used in the past for SRC include the clones 'Max 1', 'Max 3', 'Max 4', 'Hybride 275', 'Muhle Larsen' and 'Androscoggin'. Further clones that were used for SRC include 'Rochester', 'Weser 6', 'Beaupré', 'Münden', 'Monviso', 'Pegaso', and 'AF2'.

Figure 2*: Populus tremula* range [2]

Soil and climate preferences: Poplars tolerate a wide range of soil textures having also good drainage conditions. Light clay, sand, loam and humus soils are all acceptable for poplars. Poplar thrives in slightly acidic and slightly alkaline soil *pH*. The ideal range of *pH* for growing poplars is between 6.0 and 8.0. Poplars are adaptive to varying levels of soil moisture. The preference is for easy draining soil that is very moist, but not remaining wet for a long period of time. Poplar is temporarily tolerant to flooded soils. It will also tolerate dry soil and drought conditions for short time periods but it may drop its leaves because of that, affecting that way trees growth. Poplar is a fast growing species and nutrient rich soils help to ensure healthy and strong growth. For planting in low fertility soils the use of fertilizers might be necessary to improve soil fertility over time.

Diseases and insects [3] [4]:

Dothichiza bark necrosis or trunk scab caused by Cryptodiaporthe populea (Sacc.) Butin (anamorph Discosporium populeum (Sacc.) B. Sutton, syn. Dothichiza populea Sacc. and Briard, Chondroplea populea (Sacc.) Kleb.) The ascomycete Cryptodiaporthe populea is found throughout Europe and into Turkey, in the eastern parts of North America, and perhaps in Argentina (CMI Map No. 344, 1968). It is now known also in China (Zhong, 1982). It attacks both plantation trees and nursery plants, and in some areas from time to time causes a severe bark necrosis. In Britain it is common, but has so far been of minor importance, and has caused significant damage only in nurseries. In continental Europe, however, it has severely affected large trees and even caused their deaths (Schonhar, 1952; van der Meiden and van Vloten, 1958). In recent years severe attacks have occurred in northern Italy (Anselmi, 1986). The perithecia of the fungus are uncommon in Britain; they were first found there on Lombardy poplar in Gloucestershire in January 1969 (Burdekin, 1970), and mature in February and March (Ellis and Ellis, 1985). They are long-necked and wholly embedded in the host tissues with only the ostioles visible at the surface; they contain asci measuring 75-85 X 12-16 ~J-ill, each with eight two-celled, colourless, elliptical ascospores measuring 16-24 X 6-9 ~J-ill (Butin, 1958a). The anamorphic stage, now called Discosporium populeum, but formerly known as Dothichiza populea, is very common, and consists of pycnidia up to 2 mm across, embedded in the host tissues but wide open when mature, and forming waxy masses of colourless, sub-globose or egg-shaped conidia measuring 8-12 x 7-9 1-1m (Butin, 1958a; Goidanich, 1940). The pycnidia are formed throughout much of the year, from March till late autumn, and the pycnospores can survive for five years (Gremmen, 1958; Taris, 1959), though usually under natural conditions they persist at most for not more than ten months (Butin, 1962). The pycnidia cease to produce spores only in very dry weather (Goidanich, 1940). In culture, C. populea grows well in media containing malt or yeast extracts (Butin, 1958b) or in poplar extracts (Hubbes, 1959; Zhao et al., 1983). It produces an oily, partly crystalline toxin, which is partly responsible for the damage it causes (Braun and Hubbes, 1957; Butin, 1958b; Hubbes, 1959). The fungus grows best at a temperature of about 20 °C, but growth can still take place at temperatures only a few degrees above freezing (ViennotBourgin and Taris, 1957). The conidia germinate when the relative humidity is 90.5 per cent or higher (Butin, 1962), at an optimum temperature of 20 oc and at an optimum pH between 5.0 and 9.0 (Zhao et at., 1983). Various strains of C. populea exist. They differ in host specialisation, and change the colour of a poplar extract medium to various shades of yellow and brown (Braun and Hubbes, 1957; Brendel, 1965), the deepest brown colours being produced by the most pathogenic strains (Hubbes, 1959). Anselmi (1986) suggests that hypovirulent strains of the fungus may be developing in France, Italy and Yugoslavia.

C. populea is a facultative parasite that enters the tree mainly through wounds (including leaf scars and bud scale scars, and damage by insect pests as well as other mechanical injuries) (Viennot-Bourgin and Taris, 1957; Gremmen, 1958; Schmidle, 1953; Zhong, 1982), but also through lenticels (Hubbes, 1959), and through shoot tips and buds (Braun and Hubbes, 1957; Viennot-Bourgin and Taris, 1957). It has been known to enter through leaf scars following premature defoliation caused by Melampsora larici-populina (van der Meiden and van Vloten, 1958).

Soil preparation and establishment: Poplar SRC grown on agricultural land requires very good initial preparation of the soil exactly as for other conventional agricultural crops. Successful weeding has been proved as one of the most important factors for success. Weed control is usually only necessary in the first year of plantation establishment. Considering the duration of the SRC cultivation of more than 20 years, the initial impact of using herbicide in the first year is rather small. If the field is covered by an arable crop the year before planting, the weed can be controlled after harvesting using glyphosate preparation and suitable ground cultivation. In the case of excessive weed growth, cutting and removal of the vegetation should be considered to allow for effective weed control. In this case, sufficient time should be given to allow regrowth and active herbicide uptake. If there are problems with insects, application of organophosphate pesticides may be used in this pre-ploughing stage. If there are any perennial weeds remaining in late spring, an additional spraying with glyphosate may be undertaken, as late as possible before planting. The perennial weeds must have ca 3-4 leaves to achieve an effective spraying. For this late spraying, it is important that the ground is not worked before spraying. The field must be ploughed during autumn in case that hard winters or soil compaction is expected. In case that soil compaction is not an issue ploughing can be done before planting in early spring. Thereby, approximately ten days shall be waited before the site can be ploughed after herbicide application. If the soil is heavy clay, shallow ploughing is recommended, and the depth reached after harrowing must be 6-10 cm. For other soils, a minimum plough depth of 20-25 cm will be required to allow better planting, especially if the planting material will be cuttings.

Planting: Different plating strategies and operations exist and can be adapted depending on the available planting equipment, the labour costs, the available planting material, the planning for harvest etc. Planting with cuttings and managed as coppice is mainly used for SRC. Using seedlings for planting is quite similar to the widely used forest practice which aims the production of timber. Since planting in rows is the most appropriate method for SRC, rows should be as long as possible.

Planting is usually done in spring, in April-May in northern Europe and earlier in southern Europe, when weather conditions allow soil preparation. Planting with cuttings is also possible in later periods (May or June) since the material used is stored at low temperatures. Early planting offers advantages as the growing season is longer. Water availability is a more important factor than the early or late timing during spring. The common design of the SRC plantation implies distances of 2 m between rows and a distance of plants in the rows between 0.5 m and 0.8 m. This design requires 8,000-12,000 cuttings of poplars per hectare and specific planting machinery is used. Manual planting can be preferred in case that mechanical planting equipment is not available or too far away to bring it cost-efficiently to the plantation. If labour costs are lower than for hiring the equipment or if the plots are very small (usually below 1 ha), manual planting is an option.

Water needs: After establishment of SRC new plants start growing only if there is enough water available and if the soil is warm enough. The key factor for the success of the crop is the water availability, as too long dry periods avoid root development and plants could dry out. This means that in a poplar SRC more than 450–500 mm of water per growing season will be consumed.

Biomass yields: Yields of poplar crops depend very much on the location of the site which is mainly characterized by climate (temperature and water availability) and soil type. Varieties and clones have to be carefully selected for each location in order to maximize yields. In northern Europe, a main criterion for the selection may be cold tolerance, whereas in southern Europe it may be drought tolerance. Other factor affecting crop yields are management practices, pest and weed control, and nutrient management. The harvest cycle/interval is typically between 1 and 7 years, but may also be extended to 20 years in case of timber production. Usually after 20-30 years the crop is replanted or replaced by other crops. Feasible annual yields in Europe are ranged between 10 and 18 t/ha of dry woodchips, but in practice it is more close to 10 t/ha. Usually, yields of the first harvest are lower than the yields for the second and third harvests.

Harvesting and storage: There are different harvesting methods available. SRC crops can be cut and chipped in one harvesting operation. Alternatively, SRC crops can be cut first and left (as rods/stems or pre-chipped to billets) in the field in order to air-dry, whereas the chipping is carried out as a separate operation at a later stage. The machinery that can be used for mechanized harvesting is: wood harvester, tractor mounted equipment, self-propelled machines. Dedicated wood harvesters from forestry are heavy forestry vehicles employed in cut-to-length logging operations for felling, delimbing and bucking trees. A forest harvester is typically employed together with a forwarder that hauls the logs to a roadside landing.

Biomass quality and use: After biomass is harvested, it usually needs to be stored before it is either used for self-consumption or sold. Air-drying can reduce the moisture content from 50-55% down to about 30% within few months. However, wood chips from air-dried wood with water content of about 30% can be relatively easily and safely stored on open piles. The water content of woodchips should be reduced ideally to levels below 20%. Due to the small particle size, woodchips are sensitive to microorganisms if the water content is too high. Increased microorganism activities lead to increased temperatures of the material which has even caused self-ignition in woodchip storage facilities. The higher the water content the less energy efficient is the combustion since part of the energy is "lost" for vaporization. The lower heating value for wood is much higher if wood is dried than for fresh or wet wood.

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14. SAFFLOWER

Scientific name	Common name (s)	Family
Carthamus tinctorius L.	Safflower; it is also known as 'kusum' in India and Pakistan and as 'honghua' in China.	Asteraceae

Description of the crop: Safflower, member of the family Compositae or Asteraceae, is a branching thistle-like herbaceous annual (spring or winter) annual plant (Figure 1), with numerous spines on leaves and bracts. It reaches a plant height of 150 cm. The crop, after germination, has a slow-growing rosette stage in which is being produced: a) numerous leaves near ground level (Figure 2) and b) strong taproots develop that penetrate deep into the soil. After the stem elongation 3 to 5 branches are being developed; when the crop is being grown at high densities. Each branch ends to a globular flower capitulum, enclosed by clasping bracts, which are typically spiny. The flowering starts with the main branch and continues with the rest. Flowering initiates (Figure 2) when the day length is long; end of July for Europe. The total bloom stage may last for 4 weeks or more, greatly influenced by growing environment. Each head contains 15 to 20 seeds. The growing period is 110 to 150 days. The weight of 1000 gr is 40 to 50 gr.

Figure 1: *Carthamus tinctorius* L.

Figure 2: View of safflower from emergence to the harvesting time; a) early stages of growth, b) rosette stage, c) flowering initiation, d) flower capitulum, e) seed, f) maturity (source: CRES)

Origin and area of its cultivation: Safflower is native to the Old World, and the genus occurs naturally in the Mediterranean region, northeastern Africa, and southwestern Asia to India. It can be cultivated at latitudes between 20ºS and 40ºN that means that can be cultivated in whole Europe (Figure 3). Nowadays, it is cultivated for local use as oilseed or as food colorant (substitute of saffron). Today, the crop is grown for local use as an oilseed or a food colorant. Although half of the safflower production is from India only small quantiles are exported. Safflower is being also cultivated in USA, Canada. The majority of the crop production n Australia, Argentina and Mexico is exported to Japan and Europe. In China it is mainly produced for its flowers. In Figure 3 presented the crop distribution in Europe and North Africa. In Europe safflower has been included in several research projects such as IENICA, Crops2Industry[1] and Eurobioref project[2], In the later, safflower it had been compared with other oilseed crops namely cuphea, lunaria, lesquerella, sunflower, rapeseed and castor.

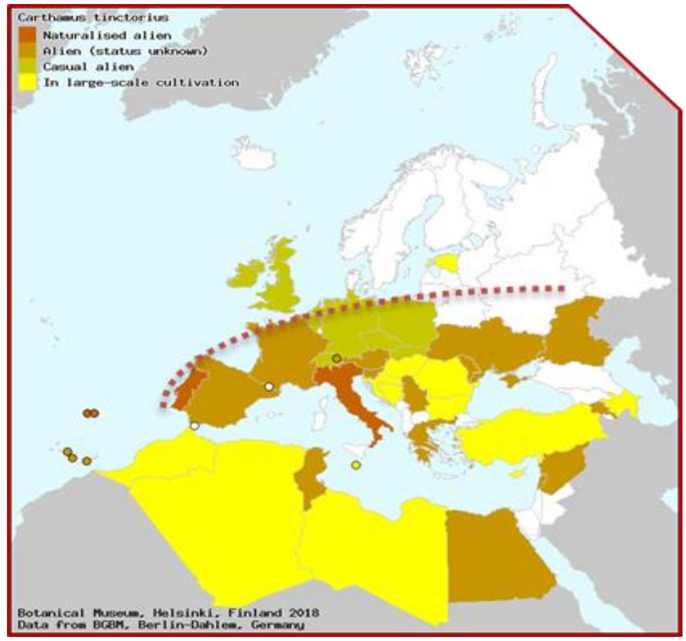

Figure 3: Safflower distribution in Europe and North Africa[3]

Varieties: Safflower varieties distinguished into two types; those having high percentage in oleic acid (74-80%) and those with high percentage in linoleic acid (70 to 80%)[4]. The high oleic varieties are used as a heat stable cooking oil to fry food, chips and other snack items and are also used in cosmetics, food coatings, and infant food formulations. The high linoleic varieties is used primarily for edible oil products such as salad oils and soft margarines, but is even used in painting in the place of linseed oil, particularly with white, as it does not have the yellow tint which linseed oil possesses.

Soil and climate preferences: The crop is adapted to semiarid regions. It grows best in deep, fertile, well-drained soils that have a high water-holding capacity. It can be grown successfully on coarse-textured soils with low water-holding capacity when adequate rainfall or moisture distribution is available. Soils that crust easily can prevent good stand establishment. The crop has a deep taproot that can penetrate to soil depth 2-3 m and thus can draw moisture and nutrients from a considerable depth and thus the crop can be grown on areas with low available moisture on the top soil. It cannot survive on soils with standing water even for few hours when the air temperature is above 20ºC. Safflower has almost the same moderate salt tolerance with values very close. During the emergence and the early stages of growth the crop has less salt tolerance. High levels of soil salinity can decrease the frequency of seed germination and lower seed yield and oil content. Safflower has approximately the same tolerance to soil salinity as barley. This crop does best in areas with warm temperatures (6-28^{0}C) and sunny, dry conditions during the flowering and seed-filling periods. During the rosette stage, the young plants can survive low temperatures (-7^{0}C)[5] but during elongation period the plant is sensitive to cold.

Diseases and insects: When the rainfalls are above the normal and in prolonged period with high humidity serious diseases have been recorded such as Alternaria (*Alternaria carthanti*) leaf spot and bacterial blight (*Pseudomonas syringae*). Alternaria leaf spot has symptoms of large, brown irregular spots on leaves and flower bracts. Varieties vary in the degree of resistance they have to leaf spot, and severe losses may occur. Bacterial blight has symptoms similar to those of Alternaria leaf spot that usually appear during periods of heavy rainfall. Diseases problems could be reduced when following a four year crop rotation in order to separate safflower with other oilseed crops (safflower, sunflower, canola, mustard, dry bean, soybean) with similar diseases.

Soil preparation and sowing: Seeding rates for optimum production vary from around 10-15 kg/ha in very drought prone regions or those where branching is to be encouraged, up to 40-45 kg/ha or even more for irrigated environments, in regions and with varieties showing minimal branching. Germination of safflower seed occurs at temperatures as low as 2-5º C. At the early stages of growth the crop is not a good weeds competitor.

Water and fertilization needs: In general, if moisture has been limiting, one good irrigation application just prior to bloom increases yield significantly. Safflower is a long-season crop with a deep taproot that can draw moisture from deep in the subsoil. Thus, it can access and utilize nutrients from below the root zone of cereal crops. Nevertheless, fertilizers tend to increase yields and oil levels, especially in irrigated or higher rainfall areas. Furthermore, in areas afflicted with dryland salinity, safflower uses surplus water from recharge areas, drawing down the moisture with the salts dissolved in it, preventing expansion of saline seeps.

Seed Yields: The seed yields varied from 2 to 3.5 t/ha. The oil content of the seeds is between 34 and 36%. Safflower seeds contain 92-93 % unsaturated fat and as such is counted as high quality edible oil. The protein content of the seed meal is 24% and with fiber content.

Figure 5: Safflower harvesting in California

Harvesting and storage: Safflower is ready to harvest when most of the leaves turn a brown color and very little remains on the bracts of the latest flowering heads green. The stems should be dry, but not brittle, and the seeds should be white and hand-threshed easily. This crop should be harvested as soon as it matures in order to avoid the seed discoloration or sprouting in the head that can occur with fall rains. Safflower is an excellent crop for direct combining since it stands well and does not shatter easily. Direct combining may require artificial drying or waiting until green weeds are killed by frosts. The crop can be windrowed to dry green weeds when moisture content of seed is as high as 25%. The time for harvesting safflower in Europe can vary from early to late September due to the environmental conditions during the growing season. Quality safflower seed should have a white seed coat, and no sprouting. Safflower seed has recently been purchased on a clean basis with a desired oil content of 34 to 36% and the moisture content should be not higher than 8% for safe long-term storage.

Figure 4: Flowers, seeds and oil of safflower

Uses: Traditionally, safflower was cultivated for its seeds and used to flavor foods and color textiles[6]. Red and yellow dyes were prepared from safflower. Extracts of the plant were also used to make medicines. More recently, in the last 50 years, safflower seed vegetable oil has been extracted on a commercial basis from the harvested seeds of the plant. The safflower seed oil is colorless and flavorless and similar in nutritional composition to the sunflower oil. It is used for cooking, salad dressing, margarine preparation, as well as in cosmetics. Two main varieties of safflower exist and they produce different kinds of oil. One variety produces oil that is high in monounsaturated fatty acid (oleic acid). This oil is primarily used in cooking. The other variety of safflower is high in polyunsaturated fatty acid (linoleic acid) and is mainly used in paintings. Another lesser known use of the plant is the use of safflower seeds in cooking as a less expensive substitute for saffron. The orange-red pigment Carthamin extracted from dried safflower flowers is used as a source of natural dye to color textiles.

As industrial oil, it is considered drying or semidrying oil that is used in manufacturing paints and other surface coatings. The oil is light in colour and will not yellow with ageing; hence it is used in white and light-colour paints. This oil can also be used as a diesel fuel substitute, but like most vegetable oils, is currently too expensive for this use. The meal that remains after oil extraction is used as a protein supplement for livestock. The meal usually contains about 24% protein and much fiber. Decorticated meal (most of hulls removed) has about 40% protein with a reduced fiber content. Foots are used to manufacture soap. The birdseed industry buys a small portion of the seed production. Sheep and cattle can graze succulent safflower and stubble fields after harvest.

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15. SORGHUM

Scientific name	Common name (s)	Family
***Sorghum bicolor* L.**	**Sorghum, great millet, durra, jowari, milo**	**Poaceae**

Figure 1: *Sorghum bicolor* L.

Description of the crop: Sorghum is an annual herbaceous spring C4 crop with erect stems that can reach 5 m height (Figure 1). The stems are large with a diameter up to 5cm and are consist of alternating nodes and internodes and each node supporting one leaf. Each stem can produce up to 30 leaves (30 -35 cm long and 1.3-15 cm wide). At the flowering one panicle is being developed on the top of each stem. The panicles can greatly vary in terms of color, size (short, compact, lose or open) and seed production. Sorghum has an extensive and deep root system with three types of roots: the primary, the secondary and the brace or buttress roots. The primary roots develop from the radicle and after their senescence the adventitious roots are being developed from the underground nodes and can extend up to 2 m depth. Adventitious roots are small and uniform and are supply nutrients to the plant. The brace roots develop from the root primordia of the basal nodes above the ground level (Figure 3). These roots provide anchorage to the plant. The weight of 1000 seeds is 13-14 g.

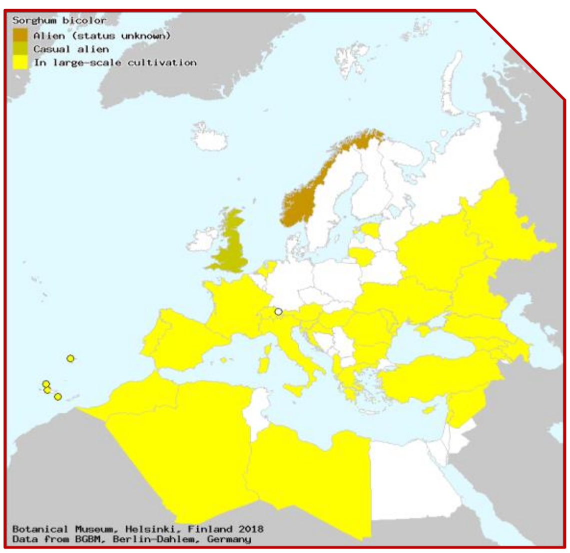

Figure 2: Distribution of *Sorghum bicolor* L. is Europe and North Africa[2]

Origin and area of its cultivation: It is originated from Africa. It was first domesticated in Sudan, Chad and Ethiopia and then it was spread first to India and China. Since the late 1980s, sorghum (sweet and fiber) had been included in several EU research projects since late 1980s. The most recently completed project is SWEETFUEL project[1] in which countries outside EU participated (India, South Africa and Brazil). Currently, in the view of BeCool project[3], sorghum has been included in the lignocellulosic crops that could be used for second generation biofuels (Figure 3).

Varieties: The commercial sorghum varieties are divided in six groups: grain sorghum, forage or fodder sorghum, fiber sorghum, broom sorghum, sweet sorghum and biomass sorghum. Grain sorghums cultivars cultivated for food and feed consumption. Fibre sorghums cultivars have high content of fibre and potentially can be used as fibre or energy crop. The broom sorghums cultivars have long and elastic branches and mainly used for brooms. The sweet sorghums cultivars have juicy stems with high juice sugar content and used as an energy and/or food crop. Finally, the biomass sorghum cultivars have high lingo-cellulosic biomass yield and used as energy crop[1].

Soil and climate preferences: Sorghum genotypes (sweet and fibre sorghum) aroused the researchers interest due to its remarkable yield potential even when grown on marginal lands[4,5]. Sorghum can be grown at altitudes from sea level up to 1000 m and at latitudes between 40^{o}N and 40^{o}S. It is primarily a plant for hot climates and thus thrives best on semi-arid tropical environments with an annual rainfall of 400-600 mm. It is a drought resistant crop and thus can be grown in areas that are considered too dry for maize cultivation. The waxy layer on the sheaths and stem contributes to reducing evaporation and increase the drought resistance. Sorghum is adapted to a wide range of soils, temperatures and soil moisture conditions. It tolerates a soil pH from 5 to 8.5 and it can survive temporary waterlogging but it does not grow well in shade. Sorghum is a short day plant, although temperatures below 20^{o}C can delay head differentiation. Sorghum plants produce sufficient juice, total sugar and ethanol yields in fields with soil salinity up to 3.2 dS/m even though the plants receive 50-75% of the water regimes typically applied to sorghum. Therefore, sorghum may be viable as an alternative crop system under increased salinity and reduced irrigation conditions, especially in semi-saline and semi-arid fields where the irrigation water is limited during crop development.

Figure 3: View of sorghum; a) a month from emergence, b brace roots, c) at the full flowering (source: CRES; BECOOL project)

Diseases, insects and weed control: Sorghum has similar pests to corn. In order to minimize the diseases and pests problems it is suggested to cultivate improved varieties/hybrids and to follow a proper rotation system. The most common disease known to attack sorghum and cause economic losses is the antrachnose. A wide variety of insect pests can affect sorghum throughout its life cycle. Insect pressure depends on location, weather and growth stage of the crop. Since the first stages of the crop, namely from sowing to canopy closure, sorghum is very sensitive to weed competition. Many weeds can infest sorghum. One which can cause an important damage in some regions in the world is the root parasite Striga spp. or witch weed, which mainly occurs under low input farming conditions. Most of the damage is done before the parasite emerges from the soil. Rotation with cotton, groundnut, and pea will reduce the incidence of Striga.

Soil preparation and sowing: The soil preparation is the same with the one followed for other spring crops (corn, cotton, etc.). The sowing for the climatic conditions of Europe should be done in spring (from the beginning to the end of April) when the soil temperature is above 12^{0}C. Due to its small seed dimension it needs an adequate preparation of the seedbed[5]. The sowing depth should be 2-3 cm on heavy soils and 3-5 on sandy ones. The plant density is depends on variety, environmental conditions, earliness and varies from 110,000 to 400,000 plants/ha. The most recommended sowing distances are: 45 to 70 cm between the rows and 10-20 cm within the rows. The seedling rate is varied between 10 and 15 kg/ha.

Water and fertilization needs: Sorghum used to be called as camel because it survives with water supply less than 300 mm for a period of 100 days. It has high water use efficiency (WUE = 193 mm of water/kg of dry matter produced or 5.2 g of dry matter/kg of water consumed). Typically, sorghum needs between 550 to 800 mm of water (rain and/or irrigation) to achieve good yields, i.e. 50-100 t/ha total above ground biomass (fresh weight). Although sorghum is a dry land crop, sufficient moisture availability for plant growth is critically important for high yields. The major advantage of sorghum is that it can become dormant especially in vegetative phase under adverse conditions and can resume growth after relatively severe drought. Sorghum is considered very efficient in utilising nutrients[7] from the soil because of a large fibrous root system. However, like other crops, sorghum needs adequate nutrients to produce good yields. Profitable responses to fertilisation can be expected on many soils. In places where soil fertility ranges from low to moderate, the fertilisation needs are about: 100-150 kg N, 60-100 kg P_2O_5 and 60-100 kg K_2O per hectare. Nitrogen application is recommended to be done in two times: before sowing and 20-30 days after the emergence.

Yields: The grain yields can be up to 0.3 - 2t/ha when it is grown rainfed conditions (India and Africa) and 4.5 to 6.5 t/ha under irrigation (USA and Australia). The yields of sorghum (fiber and sweet) can be up to 140 t/ha (on fresh basis) and 20 to 25 t/ha (oven dried).

Figure 4: View of sorghum harvesting for grain and for second generation bioethanol.

Harvesting and storage: Harvesting and logistics of sorghum differs according to the end-use (first generation bioethanol, grain and first generation bioethanol and second generation bioethanol). For first generation bioethanol production the crop should be harvesting when the sugars in the stalk juice measured to be between 15.5^0 to 16.5^0 Brix. A harvester for sugar cane it is used and the cut height of the stems should be 20 cm aboveground. In this type of harvesting it is very important the juice of the stems to be stabilized in order the decrease of the sugar juice quality and quantity to be avoided and thus the total processing period to be prolonged. The harvesting for grain sorghum is quite similar to harvesting applied to other small grains like wheat. The mechanical harvesting of the crop for both grain and stems is not yet fully organized. In general, the upper part should be removed (with the panicles) and at the same time the stems should be harvested. In India, where sorghum is being cultivated for both grain and stems, the harvesting is done manually. A forage harvester is being used when the cultivation aims to second generation bioethanol production. In this case, the harvesting time depends on the variety, on specific climatic conditions and on biomass demand and it could be done from late September to late October. The two most common methods for harvesting sorghums for biomass are swathing followed by baling or chopping of windrows, and direct forage chopping of the standing crop.

Uses: Sorghum is the fifth most important cereal in the world and an important staple food in the semi-arid tropical areas of Africa and Asia. Being a multipurpose crop and it can be cultivated, apart from grain, for: sugar juice from its stalk for making syrup or ethanol, bagasse and green foliage which can be used as an excellent fodder for animals, for gasification, for second generation bioethanol production, as organic fertiliser, for paper manufacturing or for co-generation[8,9,10]. For developing countries sorghum provides opportunities for the simultaneous production of food and bioenergy, thereby contributing to improved food security as well as increased access to affordable and renewable energy sources. For Europe sorghum is seen as a promising crop for the production of raw material for 2nd generation bioethanol.

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16. SPANISH BROOM

Scientific name	Common name (s)	Family
***Spartium junceum* L. & *Genista juncea* L.**	**Spanish broom,** or weaver's broom.	**Fabaceae**

Figure 1: *Spartium junceum* L.

Description of the crop: Spanish broom is a perennial shrub that can reach 4 m height. It has long, slender and erect stems with few branches. The stems are green when are young and at maturity turned to bark. Its leaves are small (2-2.5 cm long), long, oval and smooth. Spanish broom leaves are small, 0.5 to 1 inch (2-2.5 cm) long, oval with smooth margins (Figure 1). The leaves remain on the plant for a period of around 4 months. The inflorescence is an open terminal raceme with several flowers located on current-year shoots. In Europe the flowering starts in June and continues till September. The flowers are large and long (2.5 cm long), quite similar to pea's flowers and grow on short stalks on both sides of the main stem (Figure 2). The fruits are 5-10 cm long and contain 10 to 15 seeds. When the fruits mature and they turn to brown and open and the seeds disperse up to 3-4 m away from the parent plant. Each plant can produce 7,000 and 10,000 seeds can be produced per plant per season. The first seeds produced when the plant is at least 2 years old. The seeds can remain viable in the soil for at least 5 years. Plants re-sprout vigorously when pruned or burnt. The weight of 1000 seeds is 14-15 gr.

Figure 2**: View of Spanish broom: a) young seedlings, b) seeds, c) vegetative phases, d) full flowering and e) maturity stage[1,2]**

Origin and research in Europe: S. *junceum* has a large geographic native range extending from Mediterranean (Figure 3) in southern Europe, North Africa and the Canary Islands to the temperate western part of Asia, where it is found in sunny sites, sandy soils, often on the sidewalks and motorways. This species is classified as major weed in parts of the world where it was introduced as ornamental or hedge plant. In late 1980s a number of EU projects funded the research on Spanish broom. In these projects the crop had been compared with other energy crops as source for biofuel production, as candidate energy crop to be grown on marginal lands, as textile source.

Soil and climate preferences: Spanish broom can be adapted in a wide range of habitats and soil types with tolerance to severe drought conditions and high temperatures. It can grow on poor, dry and stony soils, where it contributes to avoid soil erosion and nutrient leaching (Figure 4). It can tolerate a wide range of pH (5.5 to 7.5); it is also adapted to soils with high salt concentrations. It thrives in full sun but also at temperatures as low as -10°C. Moreover it is a nitrogen-fixing plant and therefore could be cultivated on marginal lands due to its low input requirements. It cannot withstand prolonged waterlogging or soils with poor drainage.

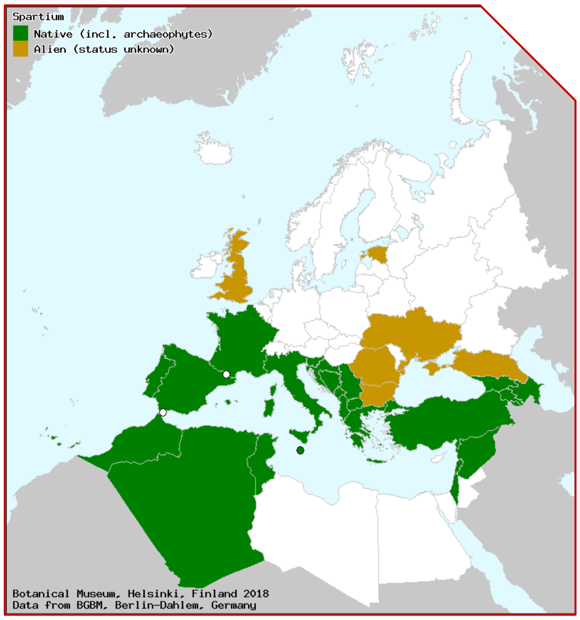

Figure 4: Distribution of *Spartum junceum* L. in Europe and North Africa[3]

Figure 4: Spanish broom invading natural grassland at the Ernesto Tornquist Provincial Park (Photograph by Cristina Sanhueza).

Diseases and insects: Spanish Broom is considered as disease resistant. At the same time, it is regarded as a noxious invasive species in places with a Mediterranean climate such as California and Oregon, Hawaii, central Chile, southeastern Australia, the Western Cape in South Africa and the Canary Islands and Azores.

Water and fertilization needs: Being a nitrogen-fixing plant Spanish broom has low N requirements. Few field trials have been established, mainly in Italy, where a pre-establishment fertilization had been applied of 100 kg/ha (NPK) and 50 kg N/ha annually at the end of winter.

Yields: The plant produce seeds after the age of 2 years and each plant can produce 7,000 to 10,000 seeds in one season; 1000 seeds can weight 15 gr approximately. Annually the dry biomass yields can be up to 20t/ha; 74% corresponding to the dry stems (14.7 t/ha). The ration between bark and the core in the stems was 0.40 (4.2:10.5).

Harvesting and storage: In Spanish broom the above ground plants are cut at the end of the growing season and vegetative regrowth generally begins at the beginning of April.

Uses: In the past, the plant was used as raw material for manufacturing ropes, nets, bags as well as clothing material, textiles, blankets, carpets, shoes, sails and biodegradable composite materials. Manufacture of products was gradually declined throughout history and in the late 19th century completely ended. There were only few associations left in Croatia trying to maintain and improve old craft, but only for the tourist attraction. Currently, Spartium is used in the paper industry as well as in the cosmetic industry, because of the intense fragrant of its flowers and the essential oils in the stems. The plant is also used as a flavoring agent and as yellow dye. It is also used in painting to create canvas, and its yellow pigment is used as a supplement of artist oil paints. The seed oil of Spanish broom is unsaturated semi-drying oil with high saponification and acidic values, which indicates that it could be used for making soap, hair shampoo and alkyd resin. The plant is sometimes harvested from the wild for local medicinal use. It is often grown as an ornamental.

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17. SUNFLOWER

Scientific name	Common name (s)	Family
***Helianthus annus* L.**	**Sunflower**	**Asteraceae**

Figure 1: *Helianthus annus* L[1].

Description of the crop: Sunflower (Figure 1) is an annual oilseed crop with an erect stem (1-3 m high). It has a tap root that can exploit moisture down to 1.5m. Its stems have branches and each one produce one composite head on the top. The cultivated types have one head on the top. Its leaves can be 4 to 20 cm and 3-15 wide. The “flower head” of sunflower contains two types of flowers; the outer ones that look like petals, they called ray flowers and they are sterile. The inner flowers called disk flowers and are those that produce the seeds (Figure 2).

Origin and area of its cultivation: Sunflower is native of North America. In 18th century became a popular cultivated crop in Russia, where the area of its cultivation in the beginning of 19th century came up to 900.000 ha. At the end of 18th century the crop came back to North America became popular again. Currently, sunflower is an important oilseed crop that cultivated worldwide. In figure 3 presented the world production on sunflower seeds. The top three sunflower producers at world level are Ukraine, Russia and European Union.

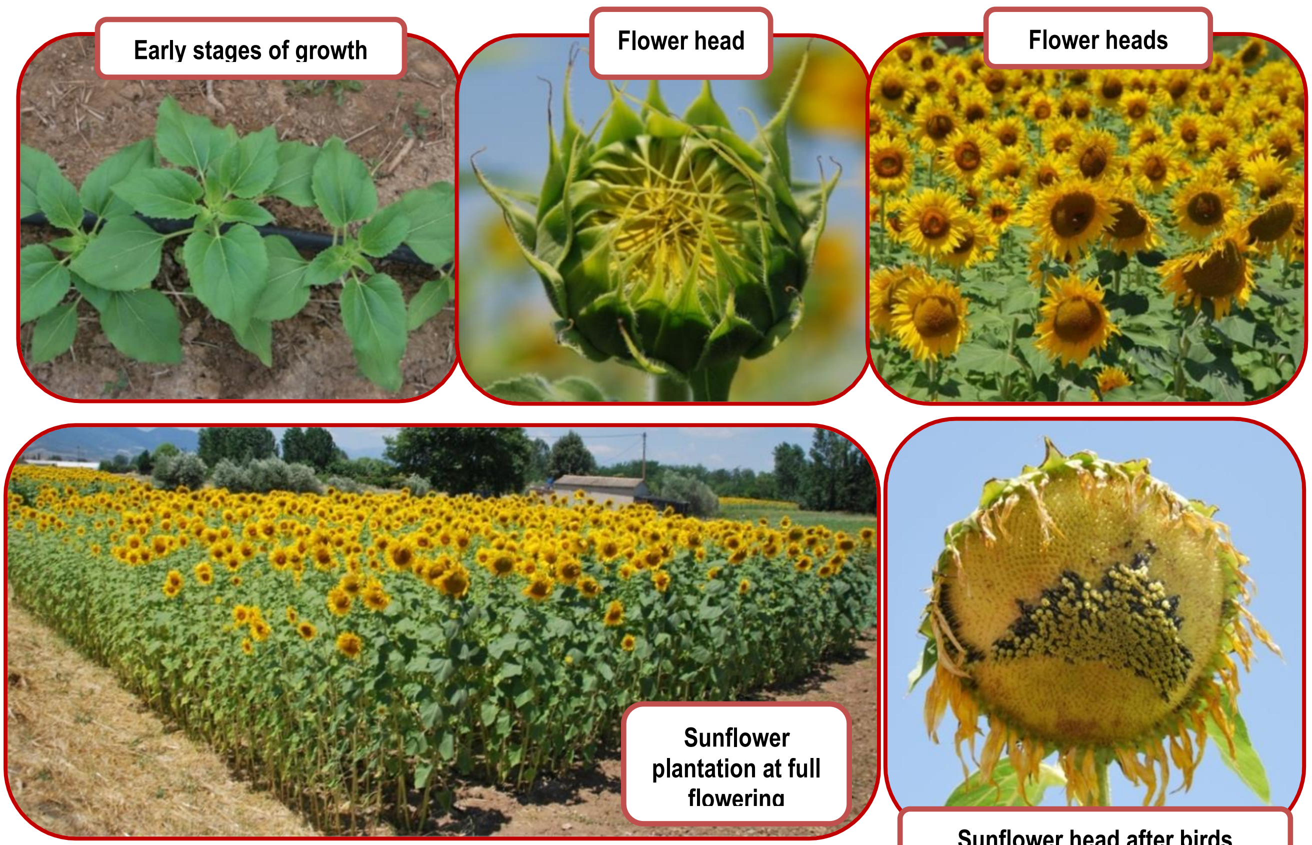

Figure 2: View of sunflower from emergence to the harvesting time (source: CRES)

Varieties: The research that had been carried out initially in Russia and later in USA resulted in high number of varieties and hybrids with high yields. Nowadays, most of the farmers that are grown sunflower use seeds of hybrids. The hybrids characterized by higher yields and resistance to pathogens. Moreover, have been produced hybrids that perform well under dryland conditions. Moreover, have been developed hybrids with high percentage in oleic acid that are appropriate for biodiesel production.

Soil and climate preferences: The hardiness of the sunflower makes it an adaptable plant that is able to survive in almost any soil conditions, except those that are water-logged. Sunflowers thrive in neutral soils, but they also tolerate slightly acidic to slightly alkaline soils (pH range from 6.0 to 7.5). The crop prefers a warm climate and needs at least 6 hours per day with direct sunshine. It is able to adapt in very warm climate. Sunflowers are full sun plants that only thrive in environments in which they are provided six or more hours of direct sunshine per day[3]. It is a crop which, compared to other crops, performs well under drought conditions; this is probably the main reason for the crop's popularity in the marginal areas of South Africa.

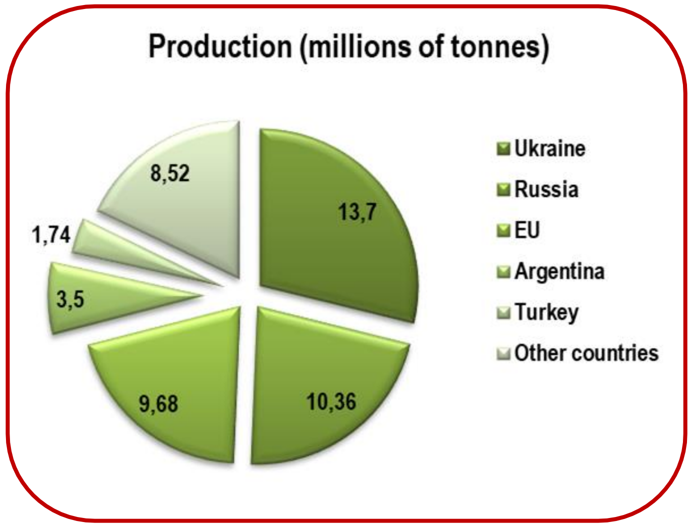

Figure 3: World production of sunflower.

Diseases and insects: One of the main sunflower diseases is Fusarium that is found largely in soil and plants. Sunflower is also susceptible to downy mildew. One major threat to sunflower crops is broomrape that is a parasite that attacks the root of the sunflower and causes extensive damage to sunflower crops. Birds can also be a problem because they sit on the heads and pick the seeds out. New hybrids have been developed with overhanging head at maturity (more difficult for the birds to hang onto).

Soil preparation and sowing: Several tillage systems have been used with some success in specific environments[4]. The final plant density should be 20.000 to 30.000 plants per ha. When the crop is going to be cultivated on marginal drylands it is recommended the density to be low, while higher densities can be applied in areas with soil moisture. Usually, the distance between the rows varies between 0.75 to 1 m. The soil depth at sowing should be between 3 and 5 cm. The soil temperature at sowing should be higher than 10^0C.

Water and fertilization needs: Sunflowers belong to a group of particularly drought-tolerant plants. As long as they receive enough water during establishment when they are developing their root system, sunflowers are able to withstand periods of drought and heat. A critical time for water stress is the period 20 days before and 20 days after flowering. If stress is likely during this period, irrigation will increase yield, oil percentage and test weight. Protein percentage, however, will decrease. The demands of a sunflower crop on soil macronutrients are lower compared to traditional crops like corn and potato. Medium to high levels of macronutrients are usually required for good plant growth. The extensive tubular root system makes this plant a heavy feeder, although it is important not to over fertilize your sunflowers, which can cause weak stems. The fertilization needs of sunflower are quite similar to those of wheat. A 1t/ha Sunflower crop will need approximately 40kg/ha N, 6kg/ha P and 30kg/ha K.

Seed Yields: Sunflower is in the top-three oilseed crops for Europe. In 2017, the total seed production come up to 10.4 million tonnes and had 19% increase compared to 2016[2].

Harvesting and storage: Sunflower is an annual plant which will ripen and dry off without the need for chemical desiccation. A sunflower crop is physiologically mature when the majority of the heads have turned yellow, and are facing down (at this stage, harvest will still be some weeks away). It can be harvested at a moisture content of 15%, but it is better to wait and harvest at 9% moisture, unless you have the capacity to dry grain on farm. Harvest can be done with a conventional header and front, but sunflower trays (1 - 2m trays or pans) must be fitted to the front (bolted to the header cutter bar) to avoid shattering losses. Sunflower reels and head snatchers reduce the amount of plant material entering the header. Heads should be largely intact when they come out the back of the machine, with any small centre seeds still present.

Uses: Sunflower is one of the most important oilseed crops that have been cultivated worldwide for several applications. The main use of sunflower is the oil production. Its oil has lower percentage in saturated fatty acids compared to other vegetable oils. After the oil extraction the seed meal can be used for animal feeding. Regardless of the method of sunflower meal manufacture, the meal can serve as the sole source of supplemental protein in diets for beef or dairy cattle. The whole seed is being used as snack food. Sunflower seed oil is also being used for biodiesel production. In Europe, two are the main oilseed crops that are being used for biodiesel and these are rapeseed in central and north Europe and sunflower in the Mediterranean region.

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18. SUNN HEMP

Scientific name	Common name (s)	Family
Crotalaria juncea L.	**Sunn hemp, Indian hemp, Madras hemp, brown hemp, and sann hemp**	**Fabaceae**

Description of the crop: Sunn hemp is an annual herbaceous short-day plant with erect fibrous ridged stems. It is the fastest growing species of the genus Crotalaria. It is considered multipurpose crop and can be used green manure, fiber and animal fodder crop. The leaves are simple, up to 12 cm long and up to 3.5 cm wide, oblong lance-like in shape, covered with short, downy hairs, and arranged spirally along the stem. The plant has a strong taproot with well-developed lateral roots. Its stems develop branches when it is grown at low plant densities. Flowering starts eight week from sowing can it is grown in areas with short days. Deep yellow flowers develop acropetaly on the inflorescence, which is a terminal open raceme.

Figure 1: ***Crotolaria juncea*** **L.**

Figure 2: Distribution of *Crotolaria juncea* L. is Europe and North Africa[2]

Origin and area of its cultivation: Sunn hemp is native to India and Pakistan[1]. In Europe sunn hemp can be found as alien crop (Figure 2). In Southeast Asia, sunn hemp has been grown as a green manure crop for centuries and now is cultivated in many tropical and sub-tropical regions worldwide. The main seed producers are: India, Hawaii, Colombia, and South Africa. In 2017, the area of cultivation for sunn hemp was 31500 ha. In USA, sunn hemp have been grown as summer cover crop that could not produce seeds since as a short day crop delay flowering initiation till the beginning of September. Sunn hemp has been selected as potential biomass in the framework of Becool project[3] and thus research trials have been established in Italy, Greece and Spain.

Varieties: Sunn hemp is a self-incompatible plant. Most of sunn hemp cultivars have originated from selection of improved types suited to specific localities, rather than by breeding procedures[4]. These selections generally focused on early maturity, improved fiber yield, and resistance to pests. More recently, genetic research and breeding procedures have been conducted on sunn hemp in Brazil and India. In these breeding programmes it had be found that the final plant height and basal stem diameter are positively correlated with total stalk dry matter, indicating selections for these traits could result in higher yielding cultivars. Some sunn hemp varieties that have recently developed in India area: Shailesh (SH-4), Swastik (SUIN-053), Ankur (SUIN-037) & Prankur (JRJ-610).

Soil and climate preferences: Sunn hemp grows well at mean annual air temperatures from 20 to more than 38^{0}C. High temperature with moderate humidity is preferable for sunn hemp growth and development. Growth may be slowed by cool weather, and the plant is susceptible to freezing injuries when the temperature is less than -2^{0}C. Although sunn hemp tolerates poor fertility soils and no fertilizer is necessary, its productivity is enhanced on fertile soils. Sunn hemp can grow well in soils with pH ranging from 5.0 to 8.4. This plant is adapted to well-drained calcareous soils and acidic sandy soils, but not to water-logged or saline/sodic soils. Sunn hemp is drought tolerant and, generally, no irrigation is necessary during the summer.

Diseases, insects and weed control: Although several insect species attack sunn hemp most of do not cause substantial economic losses and thus no chemicals are applied. In wet soils, significant yield losses can be recorded by Pythium spp. and Fusarium spp[4]. Sunn hemp is resistant to soil root-knot and soybean cyst nematodes and thus by adding sunn hemp to rotations with nematode-susceptible crops the nematode pressure could be reduce[6,7]. Due to its rapid growth it can effectively control weeds during the summer months.

Soil preparation and sowing: The soil must be prepared in such a manner that favors an adequate settlement of cultures, by using either appropriate equipment in the right period, taking into consideration that land preparation is one of the most important aspects for germination. Loose soil must be obtained, which will allow us to have an adequate sowing depth. A piece of information that must be taking into account is the sowing surface, the adequate surface must have 1 cm of soil depth. At greater seeding depths, emergence is poor. Seeds should be sown in soil temperatures greater than 20°Cfor successful germination. Seeds usually germinate readily within 3 days, and seedlings rapidly develop a dense ground cover. To establish as a cover crop, sunn hemp should be sown at a rate of 10 to 40 kg seeds per ha. Lower seeding rates can promote lateral branching. Seeds can be inoculated with cowpea inoculant to improve nitrogen fixation. The soil depth should be 2-3 cm.

Figure 3: View of sunn hemp; a) 2-leaves stage, b) three weeks from emergence, c) first flowers, d) full flowering in mid-September, e) plantation ready to be harvested (source: CRES)

Water and fertilization needs: It is worth mentioning that the Crotalaria juncea is one of the legume families; therefore, having an intrinsic capacity for the fixation of nitrogen in the soil, an action that is carried out by receiving CO_2 from the atmosphere and transforming the same into nitrogen through the fixation of the same in its roots. The fixations of nitrogen, as well as the creation of organic material and the reduction of the nematode population in the soil are their main characteristics, which make the Crotalaria juncea a green fertilizer used internationally. In its fodder use, in which the purpose is to obtain the best possible performance, in order to obtain the highest fertilizing production, as all other cultures, which must be taken into consideration. The applied fertilizers should be not rich in nitrogen and with high phosphor and potash levels.

Yields: Field tests indicate that sunn hemp can produce 800 to 2,200 kg seeds per ha when seeded in narrow rows with a grain drill. Sowing it in wide rows has been found to produce lower seed yield.

Harvesting and storage: The harvesting time is depends on the end use. When it is grown for its fibre the harvesting should be done at the flowering stage (mid-September for Europe). When the crop is cultivated for green mature the harvesting should be done two months from emergence when the plants begin to flower as it decomposes more rapidly and it will have a positive N balance at this stage. As forage crop sunn hemp should be harvested up to four times under favourable growing conditions during its growing cycle; the first 6 to 8 weeks from sowing, and thereafter every four weeks.

Figure 4: Mechanical harvest of sunn hemp for fibre (source: www.cetabol.bo) on the left and for green manure (source: Yuncong C. Li / University of Florida) on the right

It has been recommended to sun-dry sunn hemp foliage prior to feeding animals as they do not eat fresh sunn hemp. When sunn hemp has been harvested for fibre, the top portion of the stem is used for fodder or hay after mixing with paddy straw.

Harvesting can be done by hand or with a mechanical harvester. The top portion of the plants is chopped off soon after harvesting for use as cattle fodder. The main portion of the stem is left to dry on the ground during 1 to 6 days, depending on places, so that it shed its leaves and becomes ready for retting. In some areas, stems are left up to 15 days on the ground and retting occurs naturally thanks to morning dew.

Seeds can be easily harvested with a combine when most of the pods (about 70-80%) are mature. Seed maturity can be recognized by the rattling sound of the seeds within the pods. When seeds are mature, they fall to the lowest end of the pod, thus shaking the plant will produce a rattling sound. If needed, defoliation of the plants can be accomplished by spraying with a mixture of gramoxone and sodium chlorate or with a 50% solution of liquid nitrogen. Plants can be harvested with a combine with a standard header (grain platform) that needs to be raised to reduce the amount of straw going in. Concave clearance and cylinder speed need to be adjusted as needed depending on the crop conditions.

Uses: The main uses of industrial hemp are green manure, animal feeding, and fibre and seed production[8]. In India, clothing, twine, and rope are made from the fiber of older, densely grown plants[9]. In some areas, seeds are fed to pigs and horses without adverse effects. However, since some sunn hemp varieties contain moderately toxic levels of pyrrolizidine alkaloids, sunn hemp fodder and seeds are usually provided as no more than 45% of the feed ration of ruminants, swine, and horses.

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19. SWITCHGRASS

Scientific name	Common name (s)	Family
***Panicum virgatum* L.**	**Switchgrass**, all panic grass, blackbent, Wobsqua grass, tall prairiegrass, wild redtop, thatchgrass, Virginia switchgrass	**Poaceae**

Figure 1: *Panicum virgatum* L.

Description of the crop: Switchgrass is a C4 warm-season perennial grass belonging to the Poaceae family (Kingdom: Plantae, Order: Poales) with a lifespan 10-20 years depending on the area of its cultivation. It is established by seeds. The plant has erect stems with a height that could vary from 0.5 to 2.7 m. At the inflorescence open panicles 15 to 50 cm long are being developed on the top of the tillers. Switchgrass plants have a deep root system that can be up to 3 m depth.

Origin and research in Europe: Switchgrass is native of North America and thus it is considered as New World species, where it occurs naturally from 55°N latitude in Canada southwards into the United States and Mexico. Initially, switchgrass has been selected as a promising forage crop. Switchgrass has been selected as promising energy crops for USA (for lignocellulosic feedstock production (combustion, conversion to liquid or gaseous forms) in the beginning of 1980s and a decade later the research was started in Europe in the view of "Switchgrass for Energy" project[1]. Thereafter, the crop has been investigated in Bioenergy Chains project[2] and recently in OPTIMA project[3].

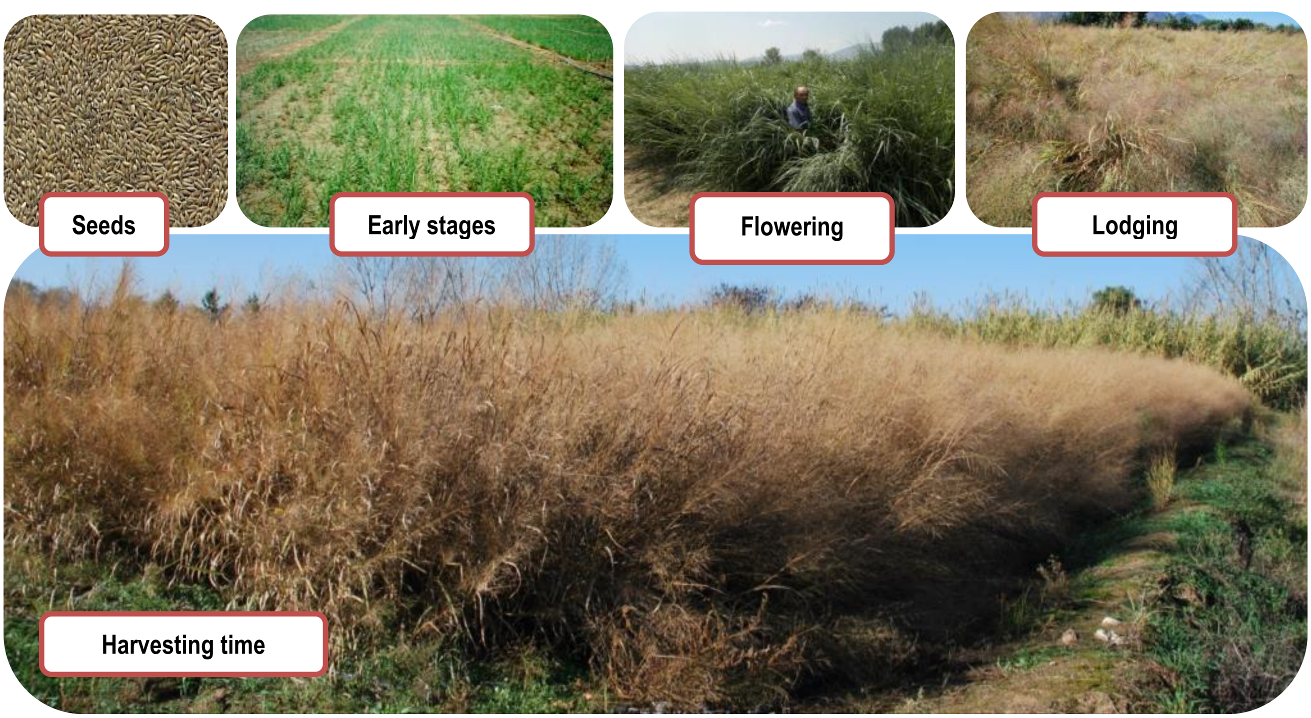

Figure 2: Switchgrass at several stages of growth (source: CRES)

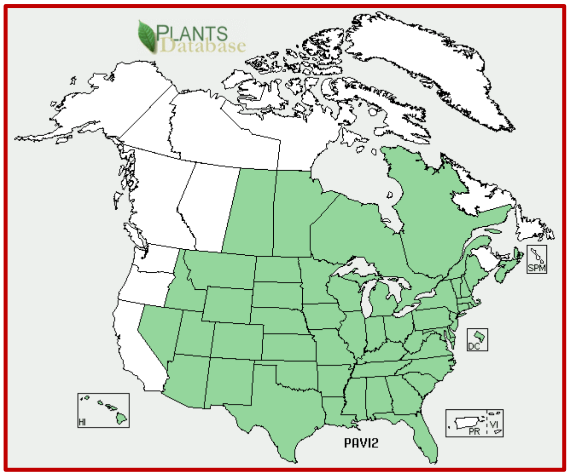

Figure 3: USDA NRCS Map; *Panicum virgatum* L. switchgrass is native throughout USA

Ecotypes and varieties: Based on the morphology and the habitat of natural switchgrass populations, two main ecotypes have been classified; **upland** and **lowland** ones[4]. *Lowland ecotypes* are taller than upland and they have longer bluish-green leaves and have longer ligules. The *upland ecotypes* are better adapted to colder and drier habitats, while the lowland ones tend to thrive in warmer and wetter habitats. European research confirms that lowland ecotypes could yield more than upland ones when grown in the pedoclimatic conditions of the South Europe[5,6,7].

Soil preferences: Switchgrass can grow under variable soil conditions ranging from sand to clay loam, although it grows best on well-drained fertile soils. Switchgrass tolerates acid and infertile soils conditions that could not be used by cool-season grasses. Although it grows best in soils with neutral pH it has been reported in some research works that the crop tolerates soil with pH from 4.9 to 7 as well as alkali soils (pH 8.9 to 9.1).

Soil preparation: A firm seedbed is recommended for proper seed placement regardless of planting method since switchgrass is planted at a shallow depth. Planting switchgrass using conventional tillage methods is a common practice for effective establishment. Conventional tillage can control or reduce cool-season weed populations and reduce residue from previous cropping systems. Conventional tillage should be avoided on fields with steep slopes because of the risk of soil erosion. For bioenergy purposes, both pre- and post-emergence herbicides are critical under no-tillage practices to control or reduce weed populations during the establishment year.

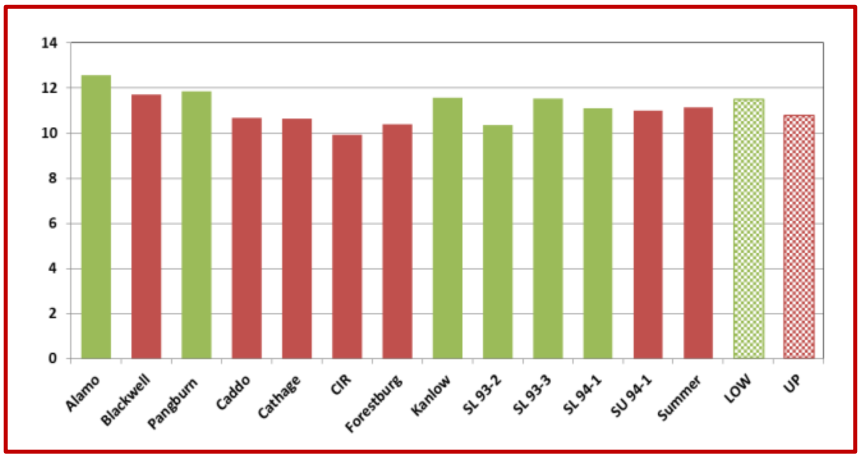

Figure 4: Mean dry yields (t/ha) of 13 switchgrass varieties (lowland in green and upland in red

Establishment: The proper planning is a key factor for the successful establishment of the crop. The main factors that should be considered for a successful crop establishment are: seedling depth, soil texture, soil moisture, and soil temperature. The recommended planting depths for switchgrass could be varied from 0.2 to 2 cm but many studies agreed that the soil depth should be no deeper than 13-mm depth. At sowing high germination rates could be ensured if the soil temperature is around or higher than 20^0C. The recommended seedling rates for switchgrass are 200-400 pure live seeds (PLS) m-2. Several row spacing (15-70 cm) have been tested.

Water and fertilization needs: Switchgrass demonstrates broad tolerance to soil moisture availability by germinating, establishing, and reproducing under both moisture deficit and flooded conditions. It have been reported that much of eastern North America is highly suitable for switchgrass production, while areas with Mediterranean climate like California is unsuitable without irrigation. In terms of fertilization it has been found that N is the most limiting nutrient for switchgrass[8,9,10]. In switchgrass the final harvest takes place in winter (after a killing frost) and some nutrients have already translocated to underground tissue[11].

Yields: Yields up 20-24 t/ha have been reported on annual basis with 20-30% moisture content. Usually, the yields maximized in the 2nd or the 3rd growing period. In Figure 4 presented the mean dry matter yields (17 years; 1998-2014) for ten switchgrass varieties when grown on marginal land in Greece. When switchgrass is being cultivated on marginal land the mean yields varied from 10-12 t/ha. Lowland varieties were productive in the Mediterranean region.

Harvesting and storage: The selection of the optimal harvest and post-harvest management practices for switchgrass is strongly depended on the end-use[12]. Although switchgrass management as energy crop is relative new, harvesting and baling could be done with commercially available haying equipment, after some modifications. It is recommended that the cutting height for switchgrass should be higher than 10 cm, which keeps the windrows elevated above the soil surface to facilitate air movement and more rapid drying to less than 20% moisture content prior to baling. The harvested material can be balled in large bales, round or rectangular, for storage and transportation. The round bales are suggested when switchgrass is going to be stored outside since they tend to have less storage losses compared to rectangular bales. The rectangular bales are easier to handle and load a truck for transport without road width restrictions.

Figure 5: Harvesting of switchgrass in Italy (Agricultural University of Bologna, Bioenergy chains project)

Biomass quality: The harvested biomass has a Gross calorific value (MJ kg-1) varied from 18.30 to 18.90 (net calorific value 17.0 to 17.6). The ash content varied among the tested varieties and could be varied from 3.85 to 5.40%. When the harvesting takes place quite late in the season (January to February) the nitrogen content of the harvesting material is quite low (<0.25%).

Uses: Initially switchgrass had been selected in 1940s as a forage crop for grazing or hay. In 1980's switchgrass has been proposed as an ideal energy crop for lignocellulosic feedstock production (combustion, conversion to liquid or gaseous forms). Nowadays, switchgrass is being investigated also as source for fiber or pulp for paper, for phytoremediation, for biomaterials, bioproducts, etc. The lignocellulosic feedstock that can be produced from perennial grasses like switchgrass has been considered as low cost biomass compared to oil, sugar and starch-rich crops and fits well to the modern bio-based economy concept to promote bio-refineries. Switchgrass has been listed in the latest EU directive 1513/2015 for the promotion of advanced biofuels, whose energy potential has been considered to be twice than the first generation biofuels. Bioethanol produced from lignocellulosic feedstock show enormous potential as an economically and environmentally sustainable renewable energy source.

Phytoremediation: Native prairie grasses are commonly used in phytoremediation strategies. Their extensive fibrous root system can penetrate up to ten feet below the surface and can result in a greater surface area than other vegetation. Phytoremediation studies have shown that switchgrass, alone or in combination with other native prairie grasses, is capable of removing atrazine from the environment.

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20. Wild tobacco

Scientific name	Common name (s)	Family
Nicotiana glauca Graham	**Mustard tree, tobacco bush, tobacco plant, tobacco tree, tree tobacco, wild tobacco**	**Solanaceae**

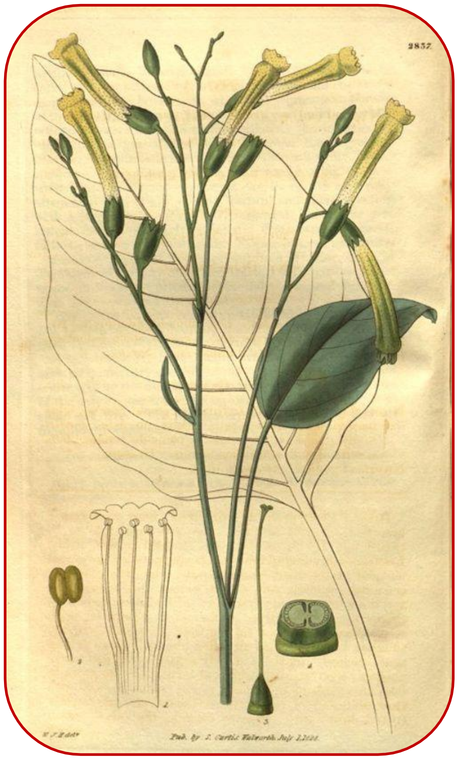

Figure 1: Nicotiana glauca Graham

Description of the crop: Wild tobacco is a branched shrub or small tree[1]. It is normally grows to a height of more than 2 m. It can reach 7 m in height. Its leaves are thick and rubbery up to 20 cm long. It has yellow tubular flowers about 5 cm long and 1 cm wide. This plant reproduces by seed.

Origin and area of its cultivation: It is native to South America. Locations within which Nicotiana glauca is naturalized include Australia, warmer parts of Europe, sub-Saharan Africa, temperate Asia, New Zealand, USA, Mexico and Hawaii. Nicotiana glauca is present in Kenya, Tanzania and Uganda. It is invasive in parts of Kenya and Tanzania[3]. It grows in open and disturbed areas.

Soil and climate preferences: Nicotiana glauca grows in a wide variety of open and disturbed habitats including roadsides and lakeshores. It is mainly a problem in relatively dry areas. It poses a threat to biodiversity by competing with native species for resources and displacing native plants[3]. All parts of the plant are poisonous. It has been included in the Global Invasive Species Database (GISD 2010). It has been listed as a noxious weed in South Africa. The distribution of the crop in Europe is presented in Figure 2. In MultiBioPro project[4] it was selected together with poplar as non-food multipurpose crops for the production of high value products following the biorefinery concept. Both these crops have the advantage that can be grown on poor marginal lands.

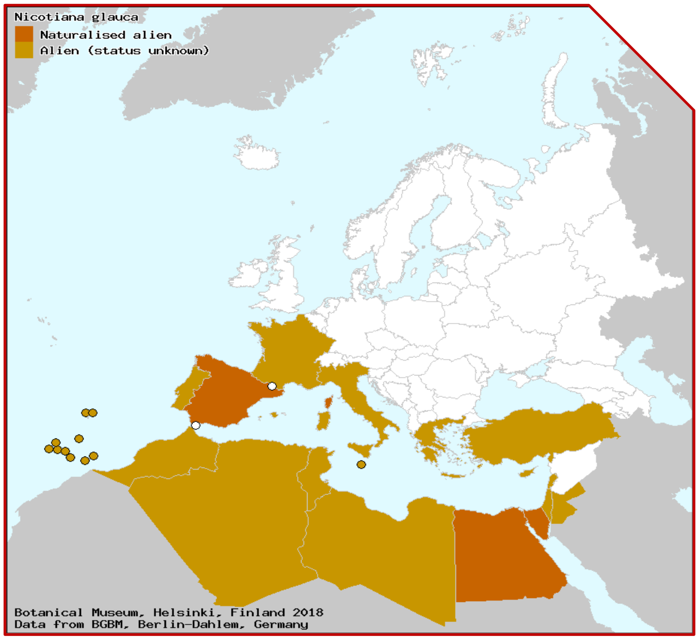

Figure 2: Distribution of Nicotiana glauca in Europe and North Africa[2]

Soil preparation and sowing: The precise management measures adopted for any plant invasion will depend upon factors such as the terrain, the cost and availability of labour, the severity of the infestation and the presence of other invasive species[5,6,7]. The best form of invasive species management is prevention. If prevention is no longer possible, it is best to treat the weed infestations when they are small to prevent them from establishing (early detection and rapid response). Controlling the weed before it seeds will reduce future problems. Control is generally best applied to the least infested areas before dense infestations are tackled. Consistent follow-up work is required for sustainable management.

Figure 3: View of the crop (http://flora.org.il/en/plants/nicgla/)

Seedlings and young plants can be pulled or dug out. Larger plants can be cut and the stumps treated with herbicide. When using any herbicide always read the label first and follow all instructions and safety requirements. The beetle *Malabris aculeata* has been released as a biological control agent for this species and has been successful when used as part of an integrated management programme.

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