



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)

Introduction

D4.2 aims to provide farmers' guidelines on how selected industrial crops could be grown on marginal lands. In MAGIC project a total number of 20 industrial crops had been selected as the most promising to be grown on marginal lands facing natural constraints in Europe. During the project lifetime a large number of field trials had been carried on around 15 industrial crops and below farmers' guidelines are being provided based on project's experiences.

Camelina

Camelina is an annual short cycling oilseed crop that can be grown both as winter and spring crop. It is considered as quite promising cover and catch crop. It is considered as promising crop for marginal lands with low inputs.

View of camelina at the flowering phase; source CRES

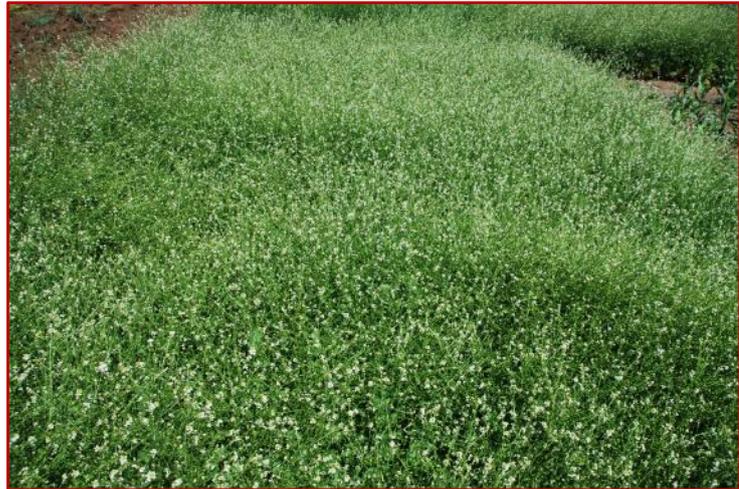


- ➔ Camelina requires well-drained soils and is able to survive through drought and frost.
- ➔ In south Europe can be grown as both winter (sowing October to December) and spring crop (end February to end March), while in central and north Europe it should be grown as spring crop (end of March to early May). In South Europe the harvesting can be done from end May to middle of June, 2-3 weeks earlier than wheat. In central and north Europe the harvesting should be done in August.
- ➔ Sowing is commonly achieved by seed that requires a seedbed of maximum 2 cm although the preferable soil depth seems to be between 6 and 13 mm.
- ➔ High plant density is recommended for a successful plantation (500 plants/m² or even higher); in high densities camelina can better compete the weeds and can provide higher seed yields. At least 6 kg/ha seeds are needed for sowing.
- ➔ There are available varieties in Europe and currently several EU projects doing research on developing improved varieties with larger seed size and improved seed yields.
- ➔ Camelina requires low nutrition up to 75 Kg N/ha, while doses that overcome this can potentially lead to lodging problems.
- ➔ The height of the plantation is usually varied from 60 to 80 cm.
- ➔ Camelina can be harvested with unmodified combines but if used, combined settings should be similar to those used for canola or alfalfa seed, while fan speed should be reduced to minimize seed losses.
- ➔ When camelina is grown on typical agricultural lands seed yields of 2 to 3 t/ha could be achieved, while when it is grown on marginal lands yields reduction up to 50% can be expected.
- ➔ The oil content on camelina seeds is around 40% (or higher) oil content.
- ➔ In dry marginal areas of Spain, camelina is being in rotation with barley. In areas of South Europe (when irrigation is available) double cropping in a year could be accomplished (camelina followed by a spring crop that can be sown at the end of May).

Crambe

Crambe is an annual short cycling oilseed crop. It is considered as quite promising cover and catch crop. It is considered as promising crop for marginal lands with low inputs. It can be grown in most EU regions.

View of crambe at the flowering phase; source CRES



- ➔ Crambe can grow on a variety of soil types with pH ranging from 5.0 to 7.8. Sandy loam soils suggest increasing crambe's yields, while saline soils seem to have an impact on crops yields.
- ➔ Sowing dates for the Mediterranean region are recommended as the second half of February.
- ➔ The seedbed for crambe should be firm in order to place seed at a uniform and shallow depth. Seed should be sown 1.5-2.5 cm deep, but up to 4 cm is acceptable,
- ➔ Crambe seeds is recommended to be sown at a rate of 10-25 kg/ha. At least 100 seeds per m² should be seeded (15 kg seeds per ha) in order to achieve density of 75 plants per m².
- ➔ The fertilization needs of crambe varied a lot and can be 30-160 kg N/ha, 40-120 kg P/ha, 60-120 kg K/ha. In sandy soils, crambe has a positive response to sulfur fertilization (like rapeseed).
- ➔ Crambe is considered to be high drought tolerant plant.
- ➔ Seed yields vary widely between 1.5 and 3 t/ha depending on environmental parameters while its oil may vary from 36 to 43%. When it is grown on marginal lands, lower yields should be expected (even 50% lower).
- ➔ Crambe can be harvested with unmodified combines and is usually direct-combined standing but can be swathed; the crop is ready to be harvested usually 90 to 100 days after planting.

Castor

Castor is an annual spring oilseed crop. It is considered as a low input crop with high seeds yields and numerous end uses. It is considered as a suitable crop for the Mediterranean region.

View of castor at the flowering phase (different hybrids); Source: CRES



- ➔ 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 is a drought resistant crop due to its tap root and due to light reflecting characteristics of its stems and leaves.
- ➔ During sowing, soil temperature must be over 12°C in order to ensure high planting rates. As for plant density it is suggested that distances between the rows to vary from 60 to 100 cm, while within the rows should be between 15 and 60 cm, 12-15 kg seeds per ha.
- ➔ The soil depth at sowing varies according to the soil type from 6 to 10 cm. While in heavy soils, sowing depth must not exceed 8 cm.
- ➔ 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.
- ➔ As for nutrients, 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 P₂O₅, 32 kg/ha of K₂O, 13 kg/ha CaO, and 10 kg/ha of MgO.
- ➔ Harvesting should be done when the capsules turn to yellow-brown, castor seeds are very susceptible to cracking and splitting at the maturity stage so, a low cylinder speed and wide cylinder concave clearance are recommended in order to minimize seed losses.
- ➔ The harvesting of castor bean is not yet well organised and currently a number of headers (sunflower headers) are being testing and improving.
- ➔ Around ten days before final harvesting a application with a herbicide is needed in order to stop the plant growth.
- ➔ There are available varieties/hybrids in the market with improved yields.

Ethiopian mustard – carinata

Carinata is an annual oilseed crop that can be grown as winter crop in areas with mild winters. It is considered as suitable for the Mediterranean region.

**View of carinata at the flowering phase;
source: CRES**



- ➔ 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 characterized by high tolerance to heat and drought and saline conditions and it is suited to a wide range of soils and pH should be 5.5 – 8.0, although it is not tolerant to waterlogging.
- ➔ As all Brassicaceae can be grown successfully on contaminated lands with heavy metals and thus can be used for phytoremediation purposes.
- ➔ In order to achieve a good establishment plant rate of 200 seeds per m² 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.
- ➔ Ethiopian mustard responds well to organic manure of up to 20 t/ha. It is commonly suggested that incorporate chemical fertilizers in the plant beds at the rate of about 100 kg N and 30 kg P is beneficial for the crop.
- ➔ Seed yields 2-3 t/ha can be expected; in the marginal lands reduced yields should be expected (30 to 50% depending on the marginality factor).
- ➔ Harvest is a critical operation and losses can be heavy due to the small seeds, early harvesting can reduce seed quality and late harvesting can enhance pod shattering.
- ➔ In the market only few varieties are available; improved varieties are needed.

Safflower

Safflower is an annual oilseed crop that can be grown both as winter or spring crop. It is considered as low input crop suitable to be grown on dry marginal lands.

View of safflower at the end of flowering phase; source: CRES



- ➔ 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.
- ➔ Germination of safflower seed occurs at temperatures as low as 2-5° C and seeding rates for optimum production vary from around 10-15 kg/ha.
- ➔ 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 fertilizers tend to increase yields and oil levels, especially in irrigated or higher rainfall areas.
- ➔ 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.
- ➔ 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.
- ➔ Seed yields between 2 to 3.5 t/ha can be expected on typical agricultural lands, while up to 50% reduction can be expected on marginal lands depending on the marginality factor. The seeds have 25 to 35% oil content.

Switchgrass

Switchgrass is a perennial grass having a lifetime 10-20 years, depending of the cultivation site. It can be grown throughout Europe by seed.

View of switchgrass at the beginning of the flowering phase; source: CRES



- ➔ Switchgrass can grow under variable soil conditions ranging from sand to clay loam.
- ➔ The crop tolerates soil with pH from 4.9 to 7 as well as alkali soils (pH 8.9 to 9.1).
- ➔ 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.

- ➔ 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°C (end of spring in south Europe). The recommended seedling rates for switchgrass are 200-400 pure live seeds (PLS) m⁻². Several row spacing (15-70 cm) have been tested.
- ➔ Switchgrass demonstrates broad tolerance to soil moisture availability by germinating, establishing, and reproducing under both moisture deficit and flooded conditions.
- ➔ In terms of fertilization N is the most limiting nutrient for switchgrass.
- ➔ In switchgrass the final harvest takes place in winter (after a killing frost) and some nutrients have already translocated to underground tissue.
- ➔ The selection of the optimal harvest and post-harvest management practices for switchgrass is strongly depended on the end-use. 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.
- ➔ Each year the regrowth take place in March (earlier than miscanthus).

Giant reed

Giant reed is a perennial grass having a lifetime 15-20 years, depending of the cultivation site. It fits best in south Europe.

View of giant reed in the middle of the summer; source: CRES



- ➔ It is established by rhizomes or stem cuttings (1-2 plants/m²), since it is a sterile crop.
- ➔ The recommended density is 20.000 to 40.000 plants per ha.
- ➔ It can tolerate hard winter and extreme heats over 35°C, while it can tolerate and balance soil erosion and heavy rainfalls, since it can flourish in many pH and soil conditions.
- ➔ It is commonly used for phytoremediation and decontamination of poor and abandoned lands, since it can tolerate, accumulate and purify heavy metals (such as Zn, Pb, Cd, Zn, Cu, Ni, Fe).
- ➔ This species requires, approximately, 375 to 560 mm of water and application with N, when the soils are having low N concentration, even though in soils with adequate N, the application of fertilization didn't show great changes, still when the fertilization occurs in mature plants it becomes profitable.
- ➔ The regrowth starts each year in April and new tillers develop for a long period till the end of the mild weather.
- ➔ Each year the harvesting should take place in winter and the dry biomass yields can be quite high (25-40 t/ha). When it is grown on marginal lands (dry lands) and under water scarcity the yields can be quite low (10 t/ha).

- ➔ Its mechanical harvesting is not yet well organised; the available harvesting machines need improvements.

MISCANTHUS

Miscanthus is a perennial grass having a lifetime 15-20 years, depending of the cultivation site. It fits well in most European regions.

View of miscanthus in the flowering time; source: CRES



- ➔ Miscanthus is suggested to be established between March and April. The most common way of establishment is rhizomes and/or rhizomes.
- ➔ There are improved genotypes that can be established by seeds but so far there used mainly for demo fields' establishment.
- ➔ Miscanthus has limited restrictions as to soil type and soil Ph and can achieve high yields in a variety of soils but prefers soil with drainage.
- ➔ It is a highly tolerant plant, that can remain unaffected when the average irrigation level is around 440 mm thus, it is considered to be one of the most well adaptive plants grown on marginal lands and rainfed conditions.
- ➔ As for the fertilization needs there is not a strong correlation between N fertilization and higher biomass production.
- ➔ Miscanthus can be harvested either in late November or in mid-April, harvest is usually conducted by conventional means usually adapted in order to process its high and stem hardness. Late November harvest usually includes miscanthus leaves while mid-April harvest lacks leaf biomass. The regrowth starts in spring, later than switchgrass.
- ➔ It is considered as crop that increase biodiversity. Moreover, it enhances the soil carbon sequestration.

Cardoon

Cardoon is a perennial herbaceous crop having a lifetime 7 to 15 years, depending of the cultivation site. It fits best in south Europe.

View of cardoon at the time of seed maturity; source: CRES



- ➔ Cardoon requires about 450 mm of annual irrigation or rainfall in order to perform well.
- ➔ It tolerates soil pH that ranges from 4.5 to 7.3 and can be resistant to soil salinity of 15 dS/cm with soil depth that ranges from 40 to 160 cm.
- ➔ Soil preparation must include ploughing in order to ensure that cardoon would easily develop a healthy root system which will increase its regeneration and yields. In

Mediterranean environments sowing is usually performed in autumn or spring so that allowing Cardoon's time for a healthy establishment before extreme temperatures of winter or summer, respectively, as a means to increase survival chances.

- ➔ Usually, the sowing takes place in rows with distances 70 to 100 cm and within the rows distances 20-50 cm.
- ➔ Fertilization seems to enrich cardoon's stalk and grain yield, while the average nitrogen fertilization needed at 120 Kg per hectare.
- ➔ The crop regrowth every autumn; the flowering takes place at the end of the winter and the crop is ready to be harvested from the middle of summer. At the final harvest, dry matter yields up 20-25 t/ha can be expected when grown in a typical agricultural land, while significant lower yields should be expected on marginal lands with shallow soil depth (5-10 t/ha).
- ➔ The harvesting machinery used, depends on the product and the machines more commonly used are forage harvesters or drum mower or biomass harvester and baler. Also, the most common practice is using a harvester and baler combine in order to secure that seed is separated from the aboveground plant biomass.

Willow

Willow is a woody species that for bioenergy purposes grown in Short Rotation Coppice (SRC). It fits best in central and north Europe.

View of willow (SRF); source crops4energy.co.uk



- ➔ *Salix* spp. is the most cultivated species in Europe, since it grows well on moist and well drained soils adding that can tolerate a great range of soils such as wet sites, alkaline, clay soils and road salt.
- ➔ Willows can grow well on soil suffering from waterlogging and it tolerates relatively poor soils and windy sites (5 to 8 pH).
- ➔ The planting site should be well-tilled and free of weeds and large stones. Full sun and minimal competition are important for the establishment of newly planted willows, after the first year. Furthermore, willows may be cut back to the ground during dormancy to promote multiple stem growth.
- ➔ *Salix* spp., has low nutritional requirements, but when the fertilization with N and irrigation occurs, results in higher production of biomass. Worthy of mention is that when fertilization is applied, the irrigation enhances the accumulation of N and C, uptake of willow.
- ➔ There are different harvesting methods available, SRC crops can be cut and chipped in one harvesting operation, alternatively crops can be cut first and then as rods/stems or pre-chipped to billets in the field. Machinery that can be used for mechanized harvesting are: a) Wood harvester, they cut trees with stems of larger diameters, the stems of SRC usually do not get very thick while smaller and lighter harvesters can be used. Harvesters usually do not include equipment for chipping, so additional machinery is needed. Sometimes gripper heads are mounted on an excavator. b) Tractor mounted equipment is available in several variations while it can be mounted on existing tractors of the SRC

operator and can include tools for combined cutting and chipping. c) Self-propelled machines are machines dedicated harvesters or modified forage harvesters that can cut and chip the crops simultaneously. After the SRC biomass is harvested, it usually needs to be stored before it is either used for self-consumption or sold.

Poplar

Poplar is a woody species that for bioenergy purposes grown in Short Rotation Coppice (SRC). It can be grown in most European regions.

View of poplar (SRF); source shortrotationforestry.it



- ➔ 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.
- ➔ For planting in low fertility soils the use of fertilizers might be necessary to improve soil fertility over time.
- ➔ 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.
- ➔ 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 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.
- ➔ Water availability is a more important factor than the early or late timing during spring. The, 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.
- ➔ 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 labor costs are lower than for hiring the equipment or if the plots are very small (usually below 1 ha), manual planting is an option.
- ➔ 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. A forest harvester is typically employed together with a forwarder that hauls the logs to a roadside landing.

Black locust

Black locust is a woody species that for bioenergy purposes grown in Short Rotation Coppice (SRC). It grows quite well in marginal lands.

View of poplar (SRF); source alfaweb.org



- ➔ Growing from October to November, blooming April to May.
- ➔ pH approximately in the range of 4.6 to 8.2, making it tolerant to plenty of soil types, even if it thrives in well drained and deep soils.
- ➔ Spacing between seedlings is about 2.4 m by 0.7 to 1.0 m (4000 seedlings/ha)
- ➔ Sowing can be accomplished both by planting seedlings developed in nurseries or with grown trees (35-40 cm depth) and by planting the seed (2 cm depth).
- ➔ In most cases, fertilization with N is not proposed.
- ➔ It is a drought tolerant species and can grow in areas with mean precipitation below 600 mm.
- ➔ Cuttings must be stored in a cool place with low moisture since high moisture can create positive conditions for fungi development. A practical difficulty when chopping black locust are the thorns, which make the manual handling hard, but it is usually harvested in the dormant season.

Siberian elm

Siberian is a woody species that for bioenergy purposes grown in Short Rotation Coppice (SRC). It grows quite well in marginal lands in the Mediterranean region.

View of Siberian Elm (SRF); source CIEMAT



- ➔ The Siberian elm is usually a small to medium sized tree growing up to 10-20 m tall, with a trunk up to 180 cm.
- ➔ It can acclimates various climate conditions including drought periods, freezes in winters, poor soils, low water supplements and winds.
- ➔ The fast-growing tree Siberian Elm is considered to be a major player in reclaimed ecosystems and post-mining areas, especially *Ulmus pumila*, since *Ulmus* spp. including Siberian elm, has abilities of phytoremediation and phytomanagement on marginal lands.
- ➔ It is suggested to plow the soil in a depth approximately of 40-50 cm in order to help the roots to form, while the removal of weeds is considered necessary action.
- ➔ The establishment of the plantation is occurring with cuttings in high density, when the establishment is for coppice regimes.

- ➔ It provides good control of the water reserves while maintaining good moisture in its soil, having low requirements in water and great adaptability. Fertilization of this establishment with NPK treatments can result in higher biomass yields, when promoting the root and upper systems to accumulate more nutrients, heavy metals and biomass.
- ➔ Usually, bark harvesters will peel bark anytime of the year. It tends to peel easiest from late March to early June while the sap is flowing. This makes sense since sap and bark harvested in the spring should be full of mucilage, sugars, and nutrients as the tree prepares to break bud. In case of infestation due to Dutch-Elm and Elm Yellows, the bark should be harvested as soon as the symptoms are first observed, because the infected trees' bark quality decline rapidly. Bark drying requires heat and airflow, adding that the strips of bark must be flat and separated in a dry area and turned daily to prevent molding. Depending on location and weather conditions, Siberian elm bark should be dry in less than a week and once it has been dried, it must be folded into strips for storage. Furthermore, when the biomass is harvested in plantations of 3-year cycle is notably much higher than those of 2-year cycle, even if the selection of the year to harvest depends on the convenience and development of suitable machinery.

Industrial hemp

Industrial hemp is an herbaceous spring crop. It is a bast fiber crop that can be grown in most European regions.

**View of industrial hemp at flowering:
source CRES**



- ➔ Hemp should not be grown on acid soils where pH is below 6.0.
- ➔ It absorbs heavy metals such as Cd, Pb, Zn, Cu, and thus contribute to the cultivation of contaminated soils.
- ➔ Industrial hemp can be sown when the average air temperature stabilizes at 8-10°C, sowing density is strongly related with the end-use of the crop, fiber production requires around 65 Kg seeds/ha with row spacing of 12.5-25 cm, while seed production requires around 15 Kg seeds/ha and 50 to 70 cm row spacing.
- ➔ The optimum fertilizers doses are: N: 90-120 kg/ha, P₂O₅: 70-100 kg/ha, K₂O: 150-180 kg/ha. For optimum yields, 250 to 300 mm of moisture during the vegetative growing stage is required, while droughts at germination and flowering phases can seriously damage the growth and yields of the crop.
- ➔ Time of harvesting depends on the purpose of cultivation of hemp. Fiber harvesting should be done in the beginning of flowering while fiber is delicate, quite strong and are appropriate to textile production. When it is grown for seeds the crop should be harvested at full maturity phase, when seeds in the middle part of panicle are mature.

Sorghum

Sorghum is a herbaceous annual spring crop. It grows very well in central and south Europe on marginal lands and with low inputs.

View of sorghum at flowering: source CRES



- ➔ Sorghum is adapted to a wide range of soils, temperatures and soil moisture conditions; it tolerates a soil pH from 5 to 8.5.
- ➔ Sorghum can be viable as an alternative crop system under increased salinity and reduced irrigation conditions.
- ➔ In Europe, it is recommended to be sown up until the end of April while soil temperatures are above 12°C.
- ➔ The sowing depth should be 2-3 cm on heavy soils and 3-5 on sandy ones, due to its small seed dimension it requires an adequate preparation of the seedbed.
- ➔ Plant density for sorghum, depends on the variety, the environmental conditions and varies from 110,000 up to 400,000 plants/ha. Recommended sowing distances are 45 to 70 cm between the rows and 10 to 20 cm within the rows, with seedling rate of 15 Kg/ha at maximum.
- ➔ Sorghum is able to withstand drought periods. Irrigation is needed when it is grown on dry lands in south Europe but it much lower compared to other annual spring crops (like corn).
- ➔ In low to moderate fertile soils fertilization needs are about: 100-150 kg N, 60-100 kg P₂O₅ and 60-100 kg K₂O per hectare.
- ➔ Grain yields can be up to 0.3 - 2t/ha when it is grown rainfed conditions and 4.5 to 6.5 t/ha under irrigation. The dry biomass yields could be quite high (35 t/ha), but can be lower (up to 50%) when it is grown on marginal lands.
- ➔ In order to produce, first generation bioethanol production the crop should be harvesting when the sugars in the stalk juice measured to be between 15.5^o to 16.5^o Brix. For advanced biofuels the total produced biomass is used.
- ➔ 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.



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