Guidelines for dual purpose industrial hemp cultivation

SCARABEO
Scarti di CAnapa - Riutilizzi Alimentari e Biovalorizzazione Energetica degli Oli

Programma di Sviluppo Rurale dell'Emilia-Romagna 2014-2020

UNIONE EUROPEA
Fondo Europeo Agricolo per lo Sviluppo Rurale
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L'Europa investe nelle zone rurali

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Realized within SCARABEO Project activities

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Introduction

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Industrial Hemp

Industrial hemp (Cannabis sativa, sativa) is an annual herbaceous plant that can reach 4-5m in height. It has a wide taproot root system (Fig. 1), from which the restructuring properties of this crop derive. It has a very fast development in the early stages of the life cycle, immediately covering the soil and thus preventing the development and flowering of the weeds.

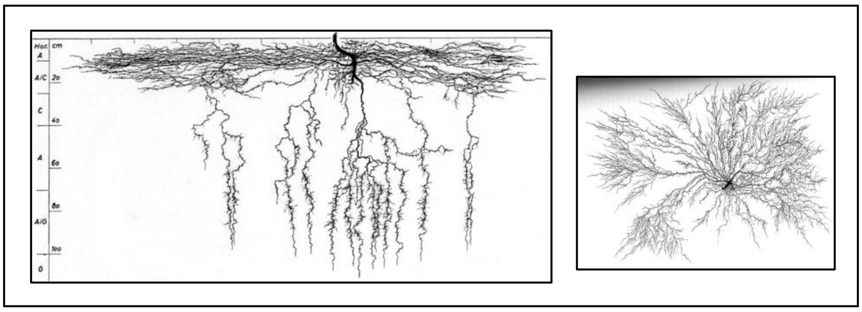

Fig. Taproot of an adult hemp plant
(https://creativecommons.org/licenses/by-sa/2.5)

Hemp has traditionally been cultivated for its fiber, contained within the stem, which is particularly long and resistant. In the hemp stem there are 2 portions: a cortical one (20-30%) called bast and a medullary one (70-80%), called hurd (Fig. 2). In the bast there are mostly long fibers (20-50 mm), rich in cellulose and slightly lignified (cellulose 50-70%, lignin 7%), while in the hurds there are mostly short fibers (2 mm) more lignified (lignin 20-30%). The long fiber / short fiber ratio is variable and generally depends on the sowing density and variety. The stem of fiber hemp is generally devoid of lateral branches, which can appear if you practice a sparse sowing (20-30 kg / ha).

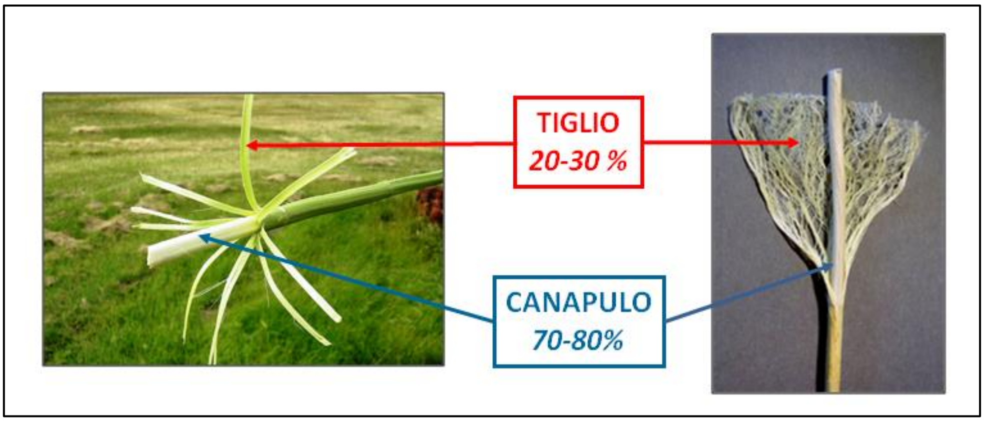

Fig. 2 *Hemp straw*

There are two types of hemp: dioecious hemp (with separate sexes) with male and female flowers carried in terminal inflorescences on different individuals (Fig. 3 ac) and monoecious hemp with male and female flowers carried on the same plant in a single terminal inflorescence (Fig. 4 a, b). In dioecious hemp the morphological differentiation of the two sexes occurs just before flowering: the males grow taller and thinner than the females and shortly after flowering they begin to dry up, while the females remain viable until the seeds are fully ripe. Traditional Italian varieties (Carmagnola, Fibranova, CS) are dioecious.

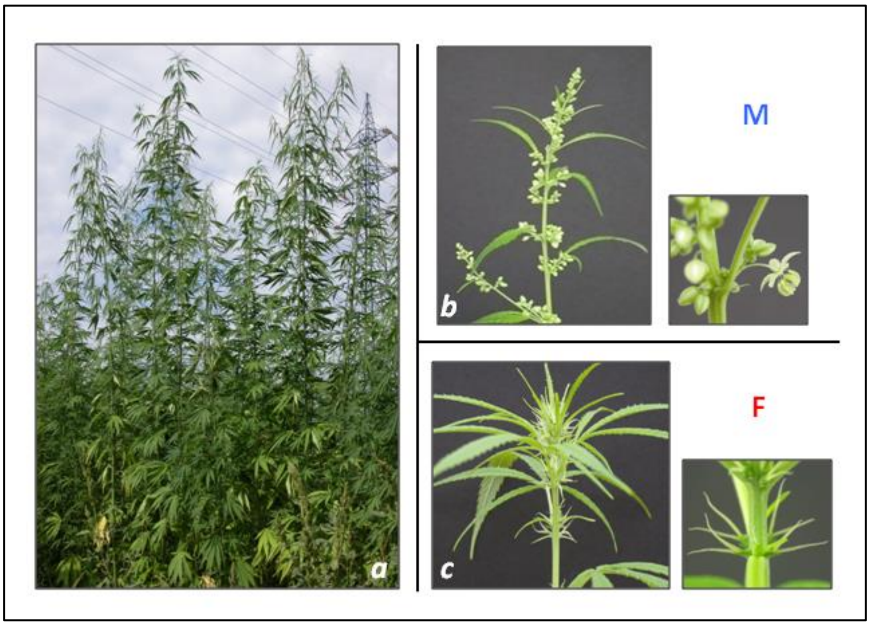

Fig. 3 dioecious hemp (a) and male (b) and female (c) inflorescences

The monoecious varieties have a bearing and a development plan that makes them more similar to dioecious females; they are more homogeneous in size and duration of the life cycle than dioecious ones. Since female flowers are present on all individuals in monoecious varieties, the total amount of seed produced by monoecious varieties is potentially greater than that produced by dioecious varieties. Actually, having a shorter cycle, monoecious compared to dioecious often have a similar seed yield.

Fig. 4 monoecious hemp (a) and monoecious inflorescence (b)

In hemp seed ripening does not occur simultaneously on the entire infructescence, but is gradual, proceeding from the bottom upwards. The hemp seed, or rather the fruit (it is an achene), has a leathery and fibrous casing (Fig. 5) and is particularly rich in fatty acids and proteins. On average, the weight of 1000 seeds is between 15 and 22 g.

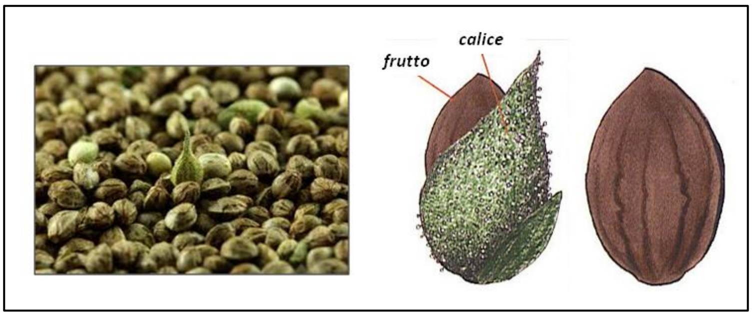

Fig. 5 Hemp seed (fruit)

Hemp life cycle (Fig. 6) lasts 5-6 months, and can vary according to the variety, sowing time and climatic conditions. In temperate climates and at our latitudes (Italy), if sowing is carried out in spring, flowering takes place after the summer solstice, when the photoperiod is reduced to 12-14 hours, and seed and stems are harvested at the end of August.

Semina & germinazione	*emergenza*	*vegetazione*	*fioritura*	*Maturazione semi*	*Senescenza*
0-10 giorni	*12-15 giorni*	*60 – 90 giorni*	*21 giorni*	*20 – 30 giorni*	*120 -150 giorni*
fine Marzo - inizio Maggio	metà Aprile - metà Luglio		metà Luglio metà Agosto	fine Agosto - Ottobre	

Fig. 5 life cycle of hemp (monoecious variety, adapted from Mediavilla et.al, 2003)

All the species belonging to the Cannabaceae family have a very active secondary metabolism, producing more than 400 different chemical compounds (terpenes, cannabinoids, flavonoids, pigments), some of which are known for their medicinal, pharmacological and psychoactive properties. There are about a hundred cannabinoids but the best known and studied are THC (tetrahydrocannabinol, psychoactive) and CBD (cannabidiol, not psychoactive). Cannabinoids are produced on the surface of female leaves and flower bracts, especially during flowering, in both monoecious and dioecious varieties. The relationship between THC and CBD concentrations is genetically determined and is referred to as a chemotype (De Mejer et al., 2003). Based on the value of this ratio, 3 different chemotypes are distinguished (Fig. 6). Chemotype I and chemotype III are prevalent among the hemp varieties available on the market and correspond respectively to medical hemp (chemotype I, prevalent THC) and industrial hemp (chemotype III, prevalent CBD). In the EU, hemp for industrial use must have a THC content of less than 0.2% (maximum 0.6% on the whole crop). In Italy it is possible to grow without any Police or other Authority permission, only industrial hemp that respects the maximum THC limit of 0.2%. It is also possible to cultivate industrial hemp for the production of CBD, a non psychoactive cannabinoid of medicinal properties. Only varieties registered in the EU variety catalog can be grown and marketed in the EU. (https://ec.europa.eu/food/plant/plant_propagation_material/plant_variety_catalogues_databases EU Plant Variety database species A - 85 - Hemp - Cannabis sativa)

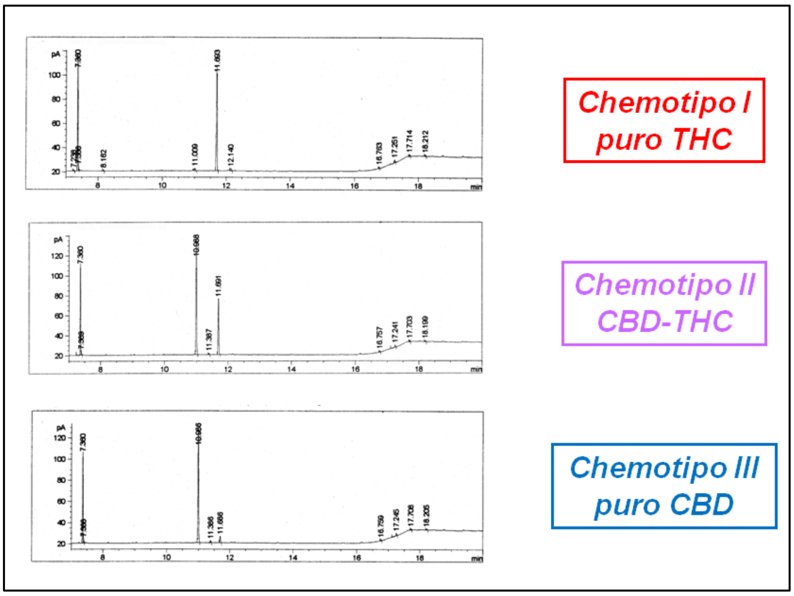

Fig. 6 Hemp classification based on chemotype

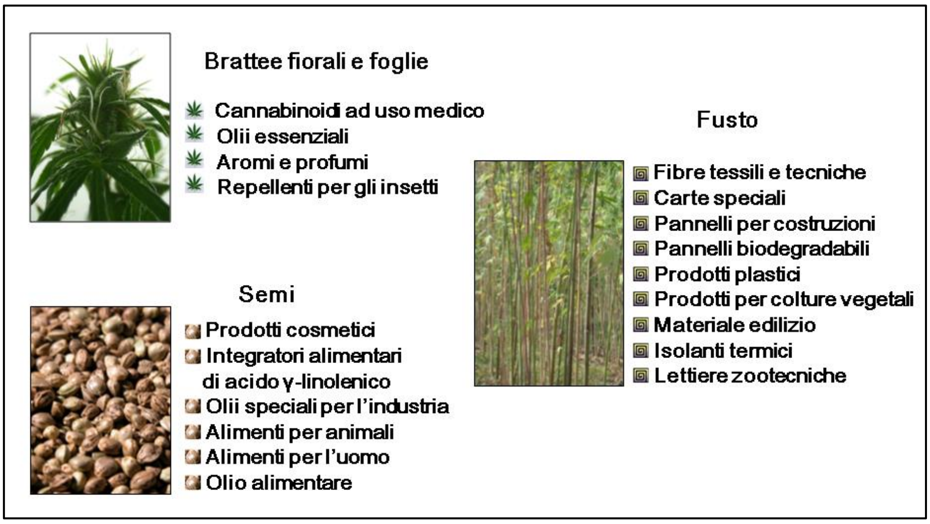

Fig. 7 Hemp products

As part of the SCARABEO project, an agro-industrial hemp chain model was developed for the production of fiber for technical and/or textile uses, and seed for food uses. Experimentation activity conducted as part of the project and the basis of these guidelines refers to a double pourpose hemp cultivation

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GUIDELINES

Hemp cultivation for fiber and seeds

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Climatic needs

Thanks to its short vegetative cycle and the many existing varieties, hemp is ubiquitous, practically cultivated or potentially cultivable all over the world. In the past, in Italy, it was cultivated from a thousand meters above sea level in Piedmont, in the Po valley, up to Campania, in the South of Italy. In fact, hemp is not particularly demanding from a climatic point of view but it achieves the best performance in warm-humid temperate climates that allow the development of large quantities of biomass. The minimum temperature for germination is + 1 ° C, but, despite the low temperature tolerated by the seed and the fact that the seedlings are quite resistant to late frosts, it is not advisable to anticipate sowing in order not to excessively lengthen the emergency period. When temperatures of 8-10 ° C are stably reached in the ground, the best conditions are obtained for a good emergence. The minimum temperature for flowering is 19 ° C and for seed ripening 13 ° C. Hemp has a double response to the photoperiod: during the first two to three months, a longer duration of the day is associated with a greater vegetative development; later, the plant requires a shorter day (12-14 hours) to flower and complete the life cycle (Ranalli and Casarini, 1998). In the period from sowing to flowering, early heat and dryness are harmful because they force the plant to pre-bloom and, therefore, to reduce the development in height. A large amount of water, if the plant is located on well-draining soils, is positive, while it is harmful if the soil tends to stagnate water because it generetes anoxia in the roots.

Rotation

Hemp is the typical spring renewal crop, it can be used with great advantages in those lands very exploited by depleting monocultures. In fact it improves the physical conditions of the soil due to the structure and size of its root system, it contains the development of weeds due to the intense competition exerted by the crop both with direct physical effects, both for shading, and for the natural mulching carried out by the crops - leaves of the basal portion- which fall on the ground partially covering it.

With current harvesting techniques, the foliar apparatus, which on average constitutes 20-30% of the fresh weight and 10-15% of the dry weight, normally remains on the ground, bringing back 60% of the phosphoric anhydride removed, and almost all of the potassium. Therefore the crops that follow in the rotation (e.g. autumn-winter cereals) benefit significantly both from its soil cleaning action and from the important mass of organic residues left on the ground (15-20 t ha-1 of fresh weight) . Spring crops also benefit from having been preceded by a hemp crop, since soil tillage is greatly facilitated. Hemp colture can follow to itself (2-3 years) without the soil accusing phenomena of mineral depletion, but for those who adhere to measures or regulations that access public funding (integrated scheme Measure 10.1.01 of the RDP of the Emilia-Romagna Region or to the Organic Regulation DM n ° 3757 of 9 April 2020) it is not possible to restore.

In the past, in the continuous alternations between wheat and hemp, during the interval between harvesting the cereal and sowing the hemp, an autumn-winter herbage was grown which was overthrown on the ground a month before sowing. Today a further useful and advisable practice not only for the fertilizing effect, but for the conservation of the organic substance in the soil and for its protective effect against harmful infestations (pathogenic fungi and nematodes) is the burying of green manure crops (cruciferous or legumes).

Variety choice

The choice of the variety is generally made on the basis of the intended use of the crop and seed availability at retailers. Generally speaking, for the production of fiber and seed the choice must fall on the monoecious varieties; for a specific production of seeds, it is preferable to choose monoecious varieties with a medium-low height that does not exceed 1.5-1.8 meters in height that allows the use of normal threshing machines for harvesting. If, on the other hand, you want to grow hemp for the production of CBD, and therefore for the collection of inflorescences, it is preferable to optate for a dioecious ones or a monoecious variety with a high CBD content. When the required product is good quality fiber (long fiber) it is necessary to have very tall plants, a characteristic that belongs mainly to dioecious varieties whose fiber content varies between 15 and 20%. Anyway, actually the variety choice strongly depends on seed availability on the market. In fact, of the 85 hemp varieties formally registered in the European variety register, only a few are actually available on the market, as happens for our traditional dioecious varieties (Carmagnola, Fibranova, C.S.). Currently the most readily available varieties on the market are French and Hungarian monoecious or Hungarian dioecious.
Some companies operating on online sales platforms provide the customer with a synoptic picture of the main characteristics of the variety (monoecious / dioecious, stem production, seed production, THC / CBD content). The retailer must provide an identification tag of the purchased variety, which guarantees that it is registered in the European variety register and has a THC content of less than 0.2%, according to regulations. This tag must be kept until harvesting. The sowing of industrial hemp in Italy is not subject to reporting to the Police; however, it is preferable to verbally warn the nearest Police station of the presence of an industrial hemp crop, to facilitate identification in the event of remote sensing.

Soil

The best soils are those of medium texture, deep, fresh, permeable and with a high content of organic matter. Good yields can also be obtained in different types of soils as long as these are not arid, with a prevalent skeleton or excessively clayey and poorly structured, with prolonged water stagnation. Particular attention must be paid to the position of the land, since good irradiation must be guaranteed. It is also necessary to avoid excessive slopes due to the consequent difficulty in using the machinery necessary for harvesting.

Seedbed preparation

The tillage required by hemp is comparable to that of other renewal crops. After plowing (traditionally 30-40 cm deep) or two-layer processing using a subsoiler plow, it is necessary to continue preparing the seedbed with refining (harrowing) in autumn or late winter based on the physical characteristics of the soil. For a regular emergence and rapid growth in all environments, a homogeneous and good refinement of the seedbed is essential. In a mountain environment, especially in soils rich in skeleton, it is preferable to replace plowing (which would bring numerous stones to the surface) with a max digging at a depth of 20 - 30 cm, with subsequent refining by harrowing. At the same time as the processing, in the lowland environments a basic fertilization with little mobile nutrients such as phosphorus and potassium is also carried out. Alternatively, hemp still responds very well to organic fertilizations (manure, poultry, slurry, digestate and compost) compatible with organic farming regulations. Hemp also absorbs high amounts of calcium, but it is rarely necessary to add it to Italian soils, as they are generally sufficiently rich in it. The crop is sensitive to the availability of nitrogen and normally poorly endowed crops turn yellow, with stunted and uneven growth. Excess nitrogen, however, is deleterious as it increases the likelihood that the crop will settle down in strong wind conditions. Today, commonly used fertilizers provide 150 kg ha-1 of N, 150 kg ha-1 of P2O5 and 100 kg ha-1 of K2O (Rivoira, 2001). When organic fertilization is the only supply of nutrients, as in mountain environments, it must be at least 300-400 q ha-1. The distribution of these elements must be done during the soil preparation operations, as well as the distribution of any amendments, such as biochar (see page 13 and following). Failure to fertilize is one of the main causes of empty seed production.

Hemp sowing

Sowing is carried out when the soil temperature has reached 10 ° C (from mid-March onwards in Italy), preferably around 12-14 ° C (Bonciarelli, 1995). Care must be taken not to delay sowing too much because in this case the risks of lack of water supply increase, to which the plants are particularly sensitive during the first phase of growth. When choosing the sowing time, the need to harvest (seed and stems) before the autumn rains must also be taken into account, to ensure drying in the field and facilitate threshing.

Delays in sowing time can cause a reduction in the number of plants per m_2 with subsequent thickening and branching of the stems which cause serious problems in the harvesting phase.

For sowing, a normal mechanical seed drill with rows of wheat is used (Fig. 8) with inter-row spacing of 13-20 cm and a sowing depth of 2-3 cm. If the soil is too dry, a slight rolling is recommended after sowing in order to favor the conservation of water in the soil.

The optimal sowing density depends on the intended use of the crop and the percentage of germination of the seed, **which should always be checked before sowing**. To obtain a good quantity of stems that are not excessively lignified and/or branched, high sowing densities are chosen (from 50 kg ha-1 up to 75 kg ha-1 considering that 25 kg bags are sold commercially). The high investment aims to force the plants to spin in order to obtain very slender stalks and suffocate the weeds, making treatment with herbicides unnecessary. Dense sowing also allows for the collection of thin and uniform stems to proceed more easily with the mechanized harvesting of seeds and stems.

Irrigation

Generally, irrigation is not practiced in regions where the irrigation supply does not lead to an increase in production (regions of Northern Italy) even if the crop may suffer from water shortages in the vegetative phase which slow down development and anticipate flowering.

Fig. 8 hemp sowing with universal seeder

Pests and stress

Hemp can be subject to abiotic and biotic stresses. Among the former, in addition to frost and late frosts during the juvenile stages, the wind that generates enticement and skidding, and the hail that can cause breakage and mortality of the plants must be considered. Among the biotic adversities we must mention cryptogams such as *Botrytis cinerea*, *Sclerotinia sclerotiorum* (causes whitish spots at the base of the stem) and numerous bacteriosis of the genus *Pseudomonas*. Among the lepidoptera, the potentially most dangerous ones are the hemp borer (*Grapholita delineana*) and the corn borer (*Ostrinia nubilalis*); these insects, when present, settle in the different parts of the plant, from the roots to the stem, to the leaves to the inflorescences. Even if these adversities can, in some cases cause damage, it is not advisable to carry out defense interventions, neither preventive nor curative. Biological control of borer can be carried out with Trichogramma brassicae, thanks to the distribution of capsules that are released based on the GPS position pre-set in the flight software of a drone.

Weed control

Hemp fears competition from weeds only in the very early stages of growth, but if it is sown early and the growth is uniform, it quickly covers itself, limiting the development of weeds and the use of herbicides. Therefore it generally does not require interventions for the control of weeds. In the case of sparse sowing for seed production, post-emergence weeding is useful. Delays in sowing can facilitate the growth of macrothermal weeds such as *Abutilon theophrasti*, *Amaranthus spp*., *Convolvolus spp*., And others, typical of corn

Seed harvesting

Hemp has a gradual maturation of the seed along the stem, for this reason it is not easy to identify the ideal harvest time. Experimental tests indicate that maximum yields are obtained by harvesting about 2 weeks after the first browning of the floral bracts. Alternatively, the harvest time is established according to the percentage of seeds ripened on a crop level (generally 50-70%).
An excessive delay in harvesting could result in a significant drop in yield due to both the fall of the seeds and the impact of birds feeding.

Conventional threshing machines such as Laverda, CASE International, New Holland, CLASS, John Deer can be used to collect the seed. Machines with axial beater such as CASE and the new John Deer would be preferred. In any case, it is necessary to reduce the forward speed of the reel and the beaters. Threshers with straw walkers and without straw choppers are preferable as it risks becoming clogged with fiber. It is essential that the blades are well sharpened to prevent the fiber from going between the blade and the blade beater. Table 1 shows the values of some salient parameters for setting the thresher

parameter	value
Hitter speed	250 spin/min
Fan speed	1070 spin/min
Grid	3,17 mm (1/8-inch)
Counter striker	9,5 mm (3/8-inch)

Tab. 1 thresher setting parameters for harvesting hemp seed

The seed must be left to dry within 4 hours of harvesting, possibly in horizontal dryers at low temperatures (25-27 ° C) and without direct heat on the seed. Alternatively, drying can be done in the air, spreading the seed on jute or hemp cloths, possibly raised from the ground to facilitate ventilation and counteract the onset of mold on the seed.

Straw harvesting

The cutting and collection of straws could present some problems, first of all the wrapping of the fiber around the rotating parts and the clogging of the cutter bar. The cut can be carried out with conventional cutter bars, preferably with double blades. The cut stems are swathed and left to dry on the ground if weather conditions permit. To facilitate drying, they can be periodically turned with a common rake. The raking favors homogeneous drying and the removal of leaves. To facilitate drying, the stems can be collected in vertical sheaves, in order to lift them from the ground, and left to dry in the sun. The collection can be done with conventional round and square balers. If the stems exceed 1.5 / 2 meters in length in the round balers, the so-called "bridge effect" could be created, ie the excessively long and elastic stem does not break, thus preventing the creation of the heart inside the round bale which will therefore result in a central hole. In any case, cutting the stems in portions of 1-1.5 meters with specific machines is advisable to facilitate the turning and packing operations.

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Use of hemp biochar in hemp cultivation

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Biochar

Biochar is charcoal obtained from the pyrolysis of different types of plant biomass. Pyrolysis is a process that allows to obtain energy in the form of gas (syngas) with a calorific value equal to LPG, and biochar or charcoal. Biochar has a carbon content of 90% and, when applied to soils, is a powerful soil conditioner. Its high porosity increases water retention and that of nutrients, which remain available for plants longer; it also improves the soil structure and its mechanical properties. Many studies have already shown the positive impact of applying biochar on agricultural yields by decreasing the need for water and fertilizers (www.ichar.org). Due to its role in regulating the water state of the soil, biochar is therefore a useful soil conditioner in the cultivation of hemp, sensitive to stagnation. The presence of biochar is also compatible with the practice of green manuring, which brings organic matter and nutrients to the soil and stimulates the growth of microorganisms. The effects of biochar on soil structure and texture are particularly appreciated in a crop such as hemp. Biochar is now allowed among soil improvers in organic farming (Legislative Decree 75/10, annex 2, italian legislation).

The compact structure of the biochar, combined with the chemical characteristics, allows this product not to be degraded by soil microorganisms and therefore to immobilize the carbon in the soil instead of returning it to the atmosphere in the form of CO_2, as in the case of compost or burning of pruning residues (www.ichar.org)

Therefore, the production and use of biochar in agriculture is a technique for the mitigation of climate change as it sequestrate carbon in the soil in an amount greater than that which it emits to produce energy. The use of biochar on agricultural land also makes it possible to reduce N_2O emissions from the soil, a greenhouse gas with a global warming potential 296 times greater than CO_2 (www.ichar.org)

Of particular interest is the production of biochar starting from agricultural residues/by-products: pruning, corn or wheat stubble, rice husk, almond husk, dry foliage. As part of the SCARABEO project, biochar was obtained by carbonizing hurds from the scutching of hemp stems.

Hurds biochar

To facilitate pyrogasifier feeding, hurds was mixed 50% with wood pellets. The particle size of the biochar obtained is mainly between 10mm and 2mm (about 75%, Tab.1). Chemical-physical analyzes revealed that hemp biochar has a basic pH, which makes it suitable for use in excessively acidic soils, and a reduced salt content. The metal content far below the limits set for use as a soil improver (IBI guidelines, www.biocharinternational.org), makes it suitable for agricultural use (Table 2)

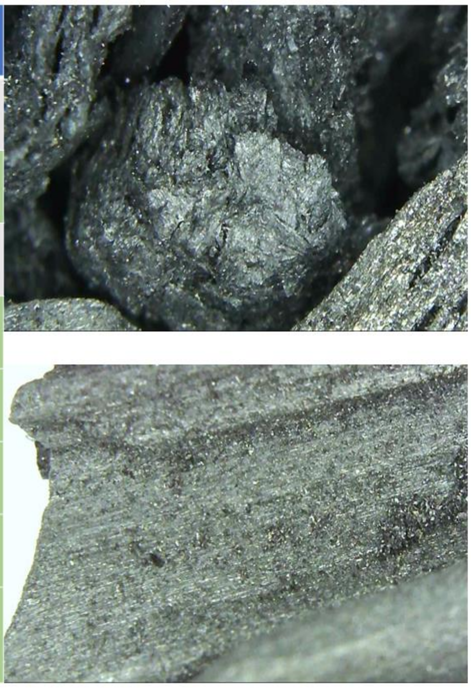
Phytotoxicity tests carried out on model plants according to official certified protocols have shown that the application of 50% hemp biochar has a stimulating effect on growth even at rather high doses (5%; Table 3).

On the contrary, plate germination tests showed an inhibiting effect of germination at the applied doses, as often occurs in tests carried out inside closed capsules (Table 3). These data were taken into account in the definition of the protocol for the use of hemp biochar in the cultivation of hemp.

Analysis	Results	Units
Granulometry	20mm: 0,0% 20mm>x>10mm: 0,5% 10mm>x>5mm: 20,9% 5mm>x>2mm: 52,8% 2mm>x>0,5mm: 13,1% <0,5mm: 12,7%	%

Tab. 1 *Hurds biochar granulometry*

Caratteristiche del biochar da canapulo	
pH	11,44
CE	2,76 mS/cm
Densità apparente	0,19 g/cm^3
Sostanza organica	83,5%
Sostanza secca	93,8%
Contenuto metalli	Entro i limiti
Contenuto IPA	4,1 mg/kg
Classe	P4 idoneo all'uso agricolo



Tab. 2 *Hurds biochar chemical-physical properties*

TEST	RESULTS	UNITS
Phytotoxicity test on *Hordeum vulgare* L.	NOT Phytotoxic Phytostimulating: > 0,5%	**%**
Phytotoxicity test on *Lactuca sativa*	**P4**. The product does not induce adverse effects on plant growth. The Product is considered suitable for agricultural use.	**%**
Germination test	Germination stimulating effect: no Phytotoxicity (EC50): 0.09 Total germination inhibition: 1	**g/plate**

Tab. 3 *results of different tests carried out on hurds 50% biochar*

Applicazione del biochar in campo

Tests carried out with hemp biochar demonstrate its suitability for agricultural use. Biochar does not provide nutrients and, if properly produced, analyzed and certified, does not bring contaminants, it follows that for agricultural use, nitrogen fertilization is essential. However, it must be considered that the same biochar could provide a certain amount of total N, even if not in an immediately available form. In areas with vulnerability problems it is advisable to estimate the amount of nitrogen supplied with the biochar to calculate, therefore, the amount of additional fertilization possible. Additional fertilization to biochar can be done in various ways:

- biochar mixed with compost, manure or other fertilizers and / or fertilizers (increases the organic matter content of the soil)
- biochar mixed with nutrients (provides an ideal habitat and favor the growth of microorganisms of the rhizosphere and soil)

The biochar can be distributed on the surface of the field or buried at a maximum depth of 15-20 cm. A deeper burial, even up to 50 cm, can be used to sequester carbon in the soil, while a more superficial burial serves to bring benefits to the roots of the plants. In optimal conditions it is recommended to apply the biochar in the preparation phase of the field, to be able to bury it freely. In the SCARABEO experiment, the distribution of biochar in the plots was superficial in the post-emergence phase, in a quantity equal to 1kg / m^2

To calculate the amount of biochar to be applied, the following indications should be taken into account

- 1 hectare of soil (10,000m2) at a depth of 25 cm corresponds to 3250 tons of soil, if we consider a density of 1.3 t / m3
- A dose of biochar equal to 1% (w/w) consist of 10 g per kg of soil, or 10 kg for each ton of soil
- A dose of 1% biochar distributed over 1 ha of soil to be buried for 25 cm therefore corresponds to 32.5 tons of biochar per hectare

- Biochar has a variable density, reaching about 0.5 g/cm^3, equal to 0.5 t / m^3; in the case of the hemp, the density of the biochar was 0.2 g/cm^3;
- Assuming a density of 0.5 t / m^3, the quantity of biochar needed to amend 1 ha of soil, 32.5 t, will correspond to 65 m^3 of biochar. Assuming a transport in 65 big bags of 1 m^3, these could require about three shipments made by van, or two shipments with articulated lorry and small tractor. This dose of biochar has a negligible effect on the volume of the treated soil; lower doses are also possible
- It must be considered that biochar is recalcitrant and remains in the soil, therefore a single application may be sufficient for several growing seasons; the data of the scientific literature are not yet exhaustive in this regard.
- It is not currently possible to estimate the cost of administering biochar over large areas because there is not yet a consolidated biochar market in Italy and Europe. However, the results of the economic analyzes carried out suggest the use of self-produced biochar with respect to the purchase on the market, with a view to the circular economy and the reuse of company by-products.

Practical indications on the distribution of biochar

The biochar can be made up of particles of variable size (Table 1), and therefore also of very small particles, or it can crumble during handling. During distribution it is therefore necessary to pay attention to minimize wind dispersion processes. Humidifying the biochar can prevent these problems, but in this case it is necessary to consider the weight gain and the resulting higher transport and distribution costs. In general, it is advisable to:

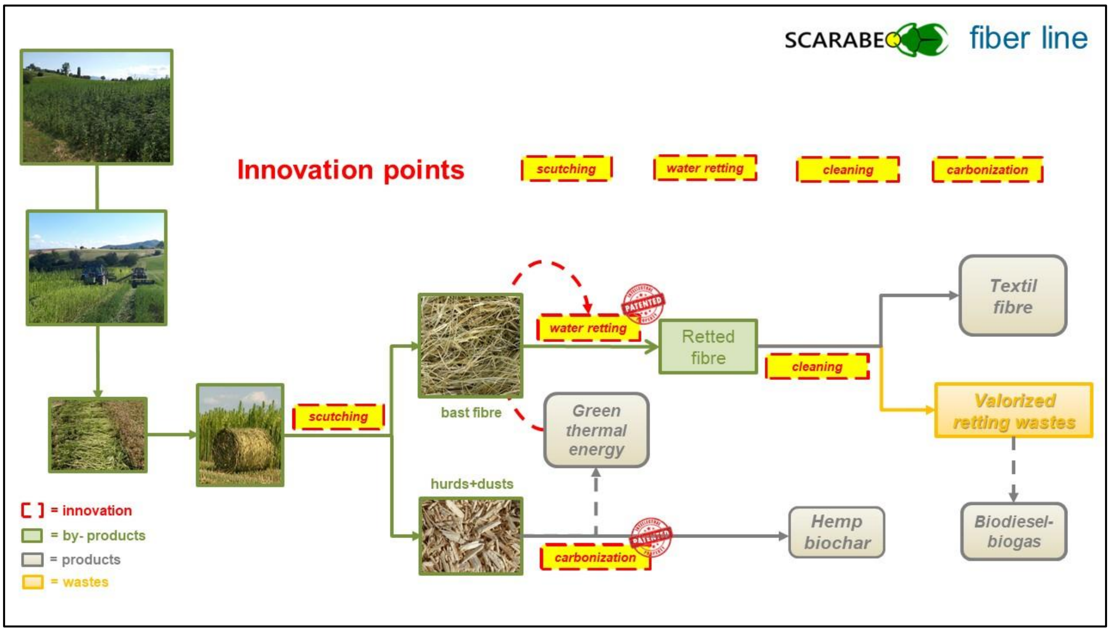
- Distribute the biochar when the wind is at its lowest, or during a light precipitation;
- Mix the biochar with water or with compost, manure, etc .;
- Use biochar transformed into pellets;
- Incorporate the distribution of biochar into normal agronomic practices to reduce costs, eg. with manure spreaders, or fertilizers
- The distribution of the biochar depends on the moment of the crop life in which it is decided to act: pre sowing, post sowing, post emergence, annual or perennial plants, etc. In the experiences carried out in the project, biochar was administered to hemp plants at the time of the emergency.

Considerazioni generali

- Preserve and store the biochar so as not to contaminate it, in "big bags";
- Remember that biochar can ignite or explode if kept in confined spaces;
- Operators must be equipped with protective clothing with dust masks and protective goggles;

The pilot agro industrial chain SCARABEO

The SCARABEO project aims to relaunch Italian hemp cultivation and trasformation, proposing an innovative supply chain of industrial hemp for seed and textil fiber production , which aims at the diversification and valorization of by-products and waste from the supply chain, maximizing revenues in an eco-sustainable way, perfectly in line with the fundamental principles of the circular economy. The figure below shows the SCARABEO work plan, highlighting the strengths of innovation:



1. As an alternative to the dew retting of whole stems, which in our latitudes and due to climate change, produces an uneven and poor quality fiber, SCARABEO proposes the scutching of the whole stems for the separation of bast fibre from hurds and the water retting of the bast fibre which contains the longest and best quality textil fibers;

2. The **carbonization** in a prototype pyrolysis engine transforms hurds into **biochar** (agricultural soil amendant) and syngas (fuel), with the **production of energy**;

3. The bast fibre water retting in a prototype retting plant (patent No. ITBO20050179 of 2006), exploiting the pectinolytic properties of the macerating flora (bacteria), allows the optimal extraction of the bundles of fibers from the surrounding tissues in just three days. The retting liquor (waste from the process, rich in pectins, reducing sugars, polyphenols), is recycled by filtration on biochar and used in the subsequent retting cycles; the enriched biochar can be used as a soil conditioner-fertilizer for agricultural uses

4. Larvae of the Diptera Hermetia illucens (L.) (Black Soldier Fly) clean the retted fiber by the film, mainly constituted by mucilage and residues of partially decomposed organic substance that cover it, feeding themselves. Conventional water cleaning is therefore replaced by a highly environmentally friendly process that transforms processing waste into larval biomass, which can be used for the production of biodiesel and protein panels to power a biogas plant.

The described supply chain model was created on a small scale and is visible at the Stuard Experimental Farm (Parma, ITALY)

THE HEMP PILOT AGROINDUSTRIAL CHAIN AT Azienda Agricola Sperim. STUARD

1) STRAW BALES SCUTCHING

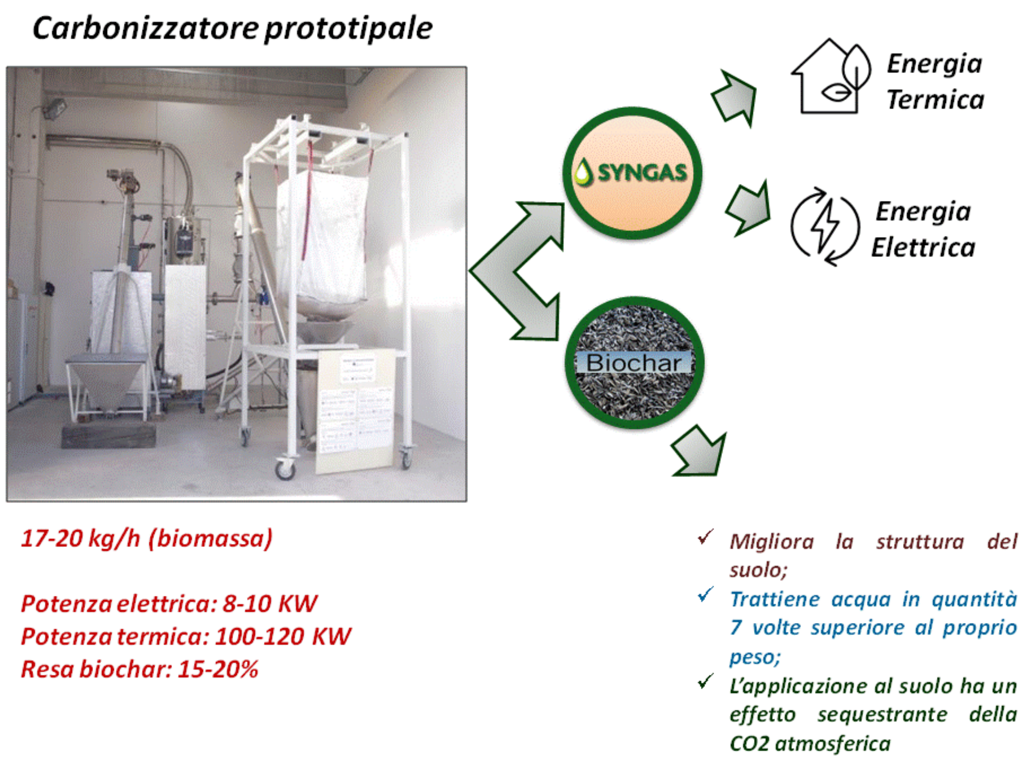
Round bales are opened and the drums, arranged on a conveyor belt, are conveyed to the scraper machine which through the action of rollers and drums separates of the bast fibre (external fibrous part) from hurds (internal part of the lignified stem). The bast fibre is collected and pressed again into bales.

Bast fibre

Hurds

2) HURDS CARBONIZATION

Il canapulo prodotto dalla stigliatura viene carbonizzato in un pirogassificatore prototipale (carbonizzatore), con la produzione di energia (syngas) e biochar.

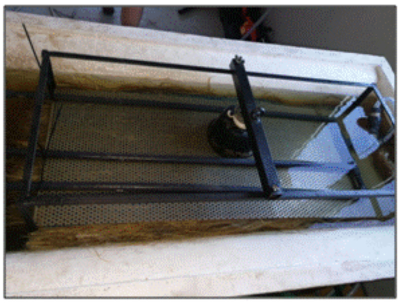


Biochar is an soil amendant with beneficial effects on the soil, crop and the environment because it is in fact unassailable carbon that traps the atmospheric CO2 fixed in the plant biomass by photosynthesis, in the soil. The carbonizer of the SCARABEO supply chain is located at the CINSA of the University of Parma.

3) WATER RETTING BIOREACTOR

PLC per il controllo remoto dei parametri della macerazione

Vasca di macerazione con sistema di caricamento della fibra

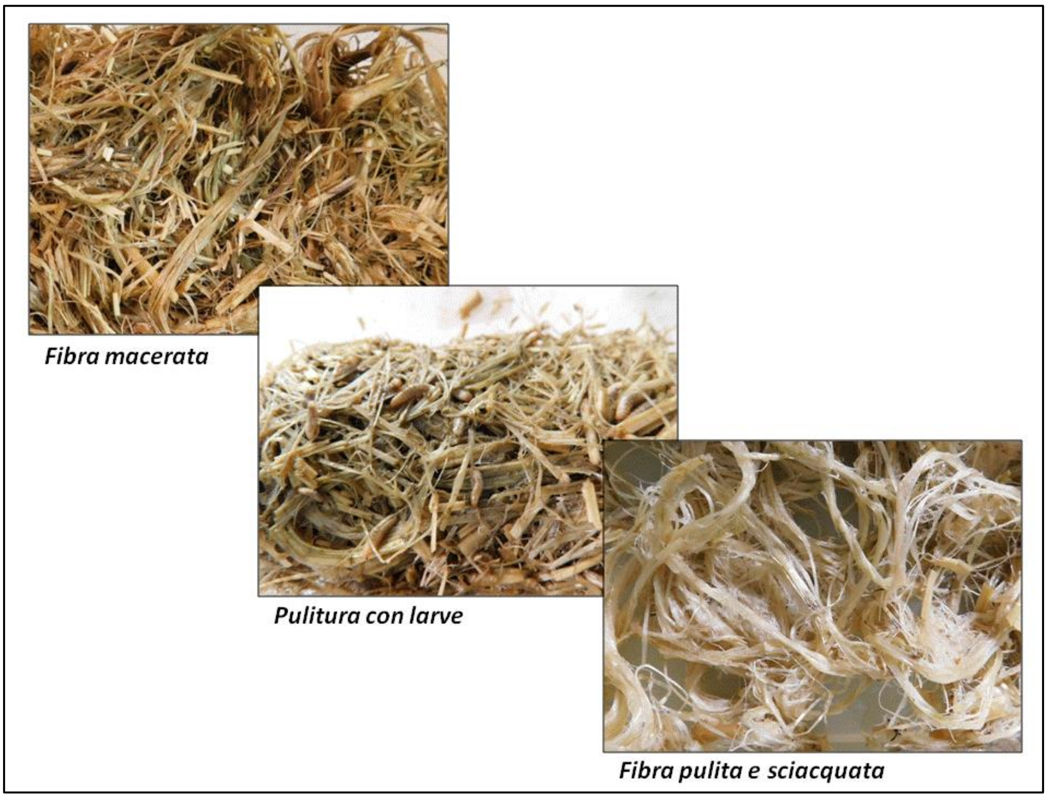


Sistema di caricamento della fibra in immersione prima della macerazione

The scutched bast fibre is arranged in layers within the loading system and immersed in water. The water is kept at a constant temperature and oxygenated through an air insufflation system. A PLC records the pH, temperature and redox potential values of each maceration. In this system, the extraction of the fiber from the lime tree is completed by the microflora (bacteria) naturally living on hemp stems, in about three days.

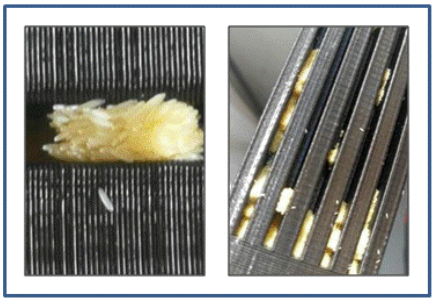
3) INNOVATIVE CLEANING SYSTEM BASED ON BSF LARVAE FEEDING

The retted fiber covered with pectins and partially decomposed tissue residues is cleaned by the larvae of the Diptera Hermetia Illucens (soldier fly). The larvae clean up the fiber and by fed increase their biomass, which is rich in lipids and proteins. Larval biomass can be used as a raw material for biogas production, making the cleaning process more sustainable.



At the Stuard farm was also set up an Hermetia illucens farm, consisting of various insect cabins in which the photoperiod, temperature and intensity of light are finely controlled by a PLC. In the cabins there are particular supports for oviposition. The larvae are reared on organic substrate consisting of the residues of the Stuard organic farm processing, until the appropriate stage of development is reached to feed on retted fibers

Insect cabins at Stuard farm for BSF adults farming



BSF ovipositors with eggs

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