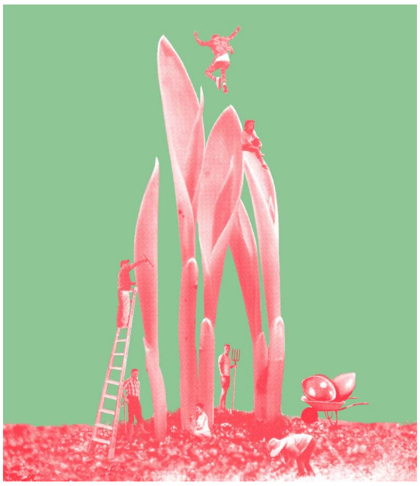
The GREAT LIFE project has received funding from the LIFE programme of the European Union

# GUIDELINES

## FOR ORGANIC MILLET AND SORGHUM CULTIVATION



**GREAT LIFE** is the European project led by the **Department of Agricultural and Food Sciences** of the **University of Bologna**. Partners include **Kilowatt**, **Alce Nero**, **Municipality of Cento** and **LCE.** From agricultural production, to processing, to consumers, our goal is to experiment with new resilient crops in order to reduce climate change impact on agricultural activities in the Po Valley, as well as in Italy as a whole, thereby helping to sustain farmers' income, reducing water consumption and producing quality foods for the final market.

**The DEPARTMENT OF AGRICULTURAL AND FOOD SCIENCES of the University of Bologna** includes all the teaching and research activities in the field of agriculture. It has two main locations, one in Bologna and one in Cesena, but also carries out both teaching and research activities in Ozzano, Cadriano, Imola and Tebano. The Department is the largest in the University of Bologna with about five hundred employees, both temporary and permanent. It is organised into specific areas to coordinate the main research activities. Each multidisciplinary group operates on all typical sectors of the agricultural field.

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# 1. INTRODUCTION

Millet and sorghum, which we consider "minor" cereals nowadays, are actually ancient and have played an important role in our diet for a long time. The fact that these cereals have been forgotten is a real shame because they have interesting agronomic and nutritional qualities. The goal of these guidelines is to promote both knowledge and cultivation of these cereals, defined as "resilient" because they are undemanding and capable of developing with good yields in hot and arid areas. Together, we will discover that millet and sorghum guarantee considerable advantages from an agronomic point of view and that they can thoroughly satisfy the needs of the farmer.

## Problem: Agriculture and Climate Change

The ongoing global climate crisis is set to continue. Annual average temperatures are rising, as are the frequency and intensity of extreme events. Moreover, polar ice shields are melting and the sea is rising. The effects of climate change vary from region to region in the Europe (Figure 1).

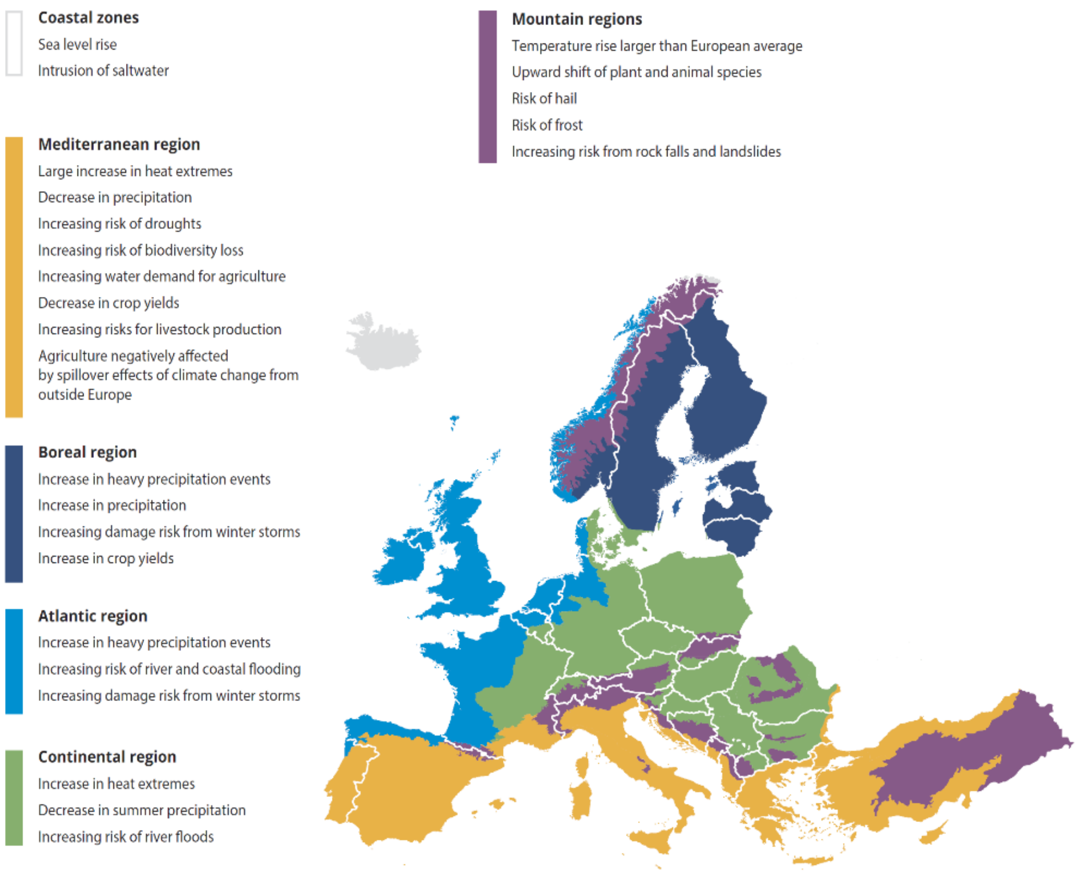


Figure 1 – Main impacts of climate change on the agricultural sector for the main biogeografiche regions in Europe (source:EEA, 2019)

In some regions, extreme weather events and rainfall are becoming more common, while others are experiencing more extreme heat waves and droughts. All of this has serious repercussions on agriculture, of which the economic sector is the most dependent on climatic conditions. This sector is experiencing serious economic losses with increasing frequency both in the short and long term. Let's think, for example, of the damage caused to orchards by the frequent late frosts that have affected various Italian regions in recent years. Or let's think of the unusually warm and dry spring and summer periods that are affecting our latitudes and that make emergency irrigation necessary to meet the water requirements of crops.

These events, in addition to the immediate damage caused, also have long-term repercussions, due to the recovery period required for the fields to become fully functional. Orchards affected by late frosts can take years to become fully functional, while soils subjected to prolonged periods of drought can undergo considerable alterations in their state of fertility, thereby compromising water retention, the transformation and decomposition of organic substances and the availability of nutrients (Figure 2). Therefore, the effects of climate change not only cause direct damage to crops, but also lead to a progressive change in the **agricultural ecosystem**, or **agroecosystem**. According to Coldiretti, the major association representing Italian agricultural entrepreneurs, the damage caused by climate change in the last decade has cost the Italian agricultural sector 14 million euros between production losses and damage to infrastructure in the countryside.

Figure 2 – Effect of heavy rains and prolonged drought on soil structure and on the growth of a fodder crop.



The challenges of climate change are obliging us to reconsider the structure of our agroecosystems. It is necessary to identify and implement both climate change adaptation strategies and mitigation strategies for greenhouse gas emissions, of which the agricultural sector is an important source. Making an agroecosystem less vulnerable to the effects of climate change means implementing actions that increase «**resilience**» (Figure 3). To do this, it is necessary to adopt a systemic approach which reduces the use of pesticides and fertilizers. On the one hand, this approach promotes methods of integrated control against harmful organisms, also exploiting the effect of crop rotations on the biological cycles of pathogenic organisms, weeds and harmful insects. On the other hand, this approach improves soil management to preserve fertility and water resources. Since the resilience of agricultural systems is closely linked to **biodiversity**, these must be safeguarded. Resilient agriculture should, therefore, be able to adapt quickly to the conditions that arise from time to time and, given their scarce predictability, this ability must become intrinsic to the system.

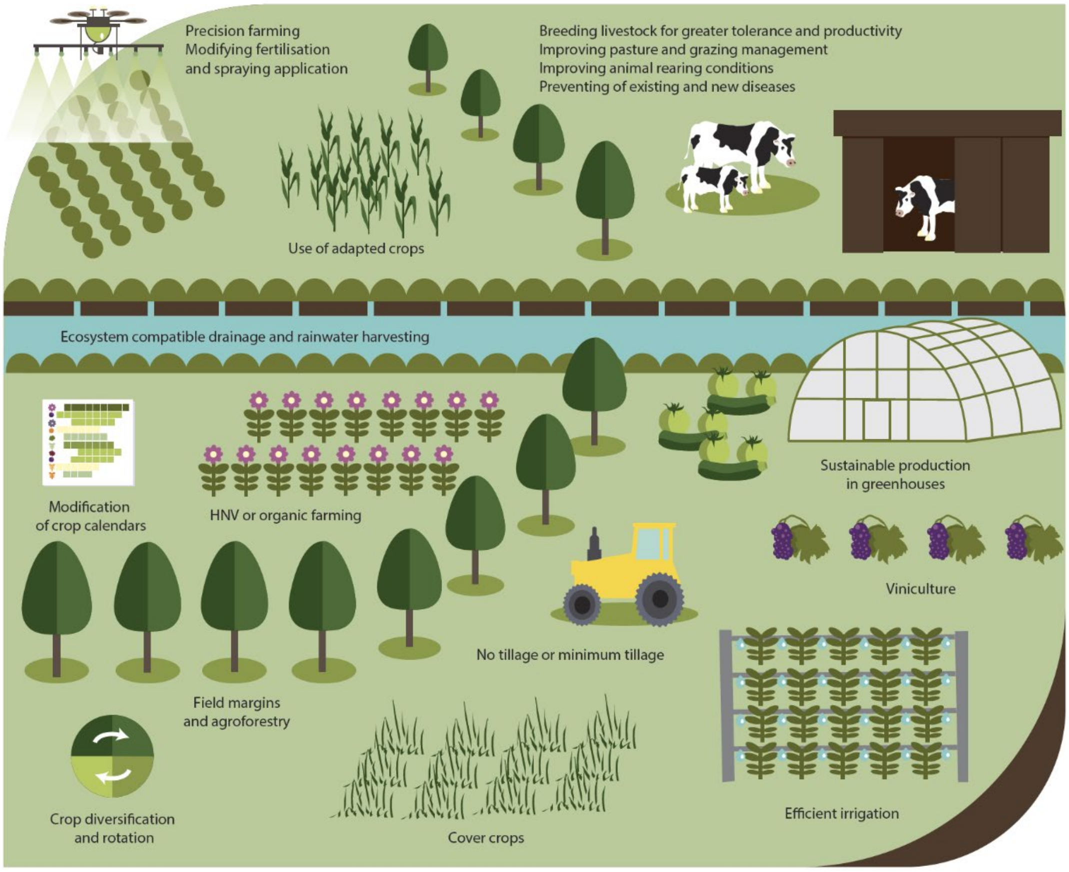




Figure 3 – Enterprise-wide adaptation measures (source:EEA, 2019)

## GREAT LIFE's answer to climate change: millet and sorghum as vectors of resilience

The GREAT LIFE project responds to the climate challenge by promoting the adoption of crops capable of adapting to limiting climatic conditions such as rising temperatures and reduced rainfall, representing the main problems for the Po valley area in the summer season. In addition to the crop choice, adopting low-impact agronomic techniques is also considered very important. These techniques are aimed at preserving the health of the soil and biodiversity or, in other words, the functionality and resilience of the agroecosystem. This constitutes an evident advantage for the production system, not only as a business unit but also as an integral part of the territory and the rural landscape.

Promoting the inclusion of new plant products in the **food supply chain** involves the need to think of crops that are not only resilient and capable of adapting to climate change, but that are also qualitatively suitable for the end-use goal (Figure 4). The quality of plant products is the combined result of a series of intrinsic and extrinsic characteristics. We can talk about *nutritional quality* when the aspect of interest is the content in carbohydrates, fats, proteins, fibre and vitamins. Instead, when the aspect of interest is

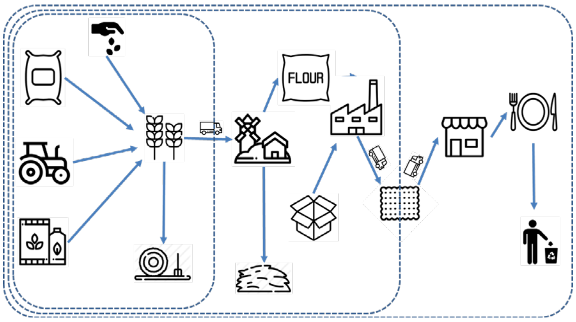


Figure 4 – Food supply chain: from production, to processing and to consumers.

the *organoleptic quality,* the product is evaluated on the basis of the sensory characteristics that we perceive with the sensory organs such as taste, smell, touch or sight. The *technological quality* refers to the properties of interest that influence the transformation process. Another type of quality that arouses some interest in the market and among consumers is the *nutraceutical quality.* The latter is the set of properties that have positive effects on health and that depend on the presence of various biochemical compounds such as antioxidants.

The approach implemented by the GREAT LIFE project is to face the challenge of climate change through the adoption of crops and cultivation techniques that guarantee not only a resilient and low environmental-impact agricultural system, but also food products that are healthy for the customers. Our proposal is to cultivate two summer cereals, **millet** and **sorghum** (Figures 5 and 6), as well as to use agronomic techniques such as rotations and tillage which confer resilience to the agricultural ecosystem. The objective is to obtain positive effects on several aspects of production ranging from cultivation to the qualitative characteristics of the product, and including biodiversity protection as well as the conservation and regeneration of the fertility of cultivated fields.

Figure 5 – Sorghum plant

Figure 6 – Millet panicle

Millet and sorghum, which are considered minor cereals today, are actually ancient cereals that have always been cultivated in our territory. Currently they are principally used in the production of animal feeds and energy. However, they possess remarkable nutritional qualities that make them highly suitable for human consumption. Both crops are low cost, characterized by low water requirements, a good resistance to drought conditions, and are well-adapted to different types of soil and agronomic managements, including low impact.

# 2. SOIL MANAGEMENT AND CONSERVATION AGRICULTURE

**Conservation agriculture** represents a multipurpose response to the need to protect agroecosystems from the dangers that threaten their equilibrium. It is defined by the Food and Agriculture Organization (FAO) as «An agricultural system that promotes minimal soil disturbance (no-till farming), maintenance of a permanent soil cover and plant species diversification. It improves biodiversity and natural biological processes above and below the soil surface, which contribute to a greater efficiency in the use of water and nutrients leading to an improved and sustainable agricultural production» (Figure 7).

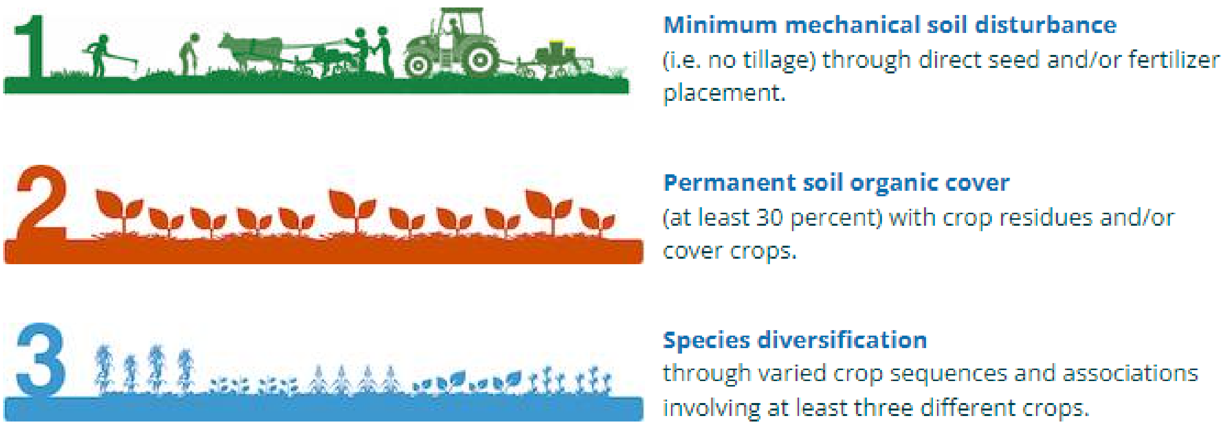


Figure 7 - Three principles of Conservation Agriculture. Source: https://www.fao.org/conservation-agriculture/en/

The main benefits of conservation agriculture include the reduction in erosion, the conservation of water and organic matter in the soil, and the improvement or conservation of the physical, chemical and biological fertility of the soil. In addition to the advantages directly linked to the soil, conservative agriculture allows for greater flexibility in agricultural operations. This promotes an improved efficiency of labour and a reduction in the number of mechanical passages on the soil with positive effects on soil porosity and fossil fuel savings. Furthermore, the use of simplified soil tillage systems assists in maintaining the costs for the preparation of the seedbed (Figure 8).


Figure 8 – Disc harrow to achieve minimal soil processing

- **CROP ROTATION AND GREEN MANURE**

Crop rotation, namely, the recurrent succession of different kind of crops on the same land (Figure 9), is the starting point and the main expedient for managing soil fertility by controlling weeds and any phytosanitary problems.

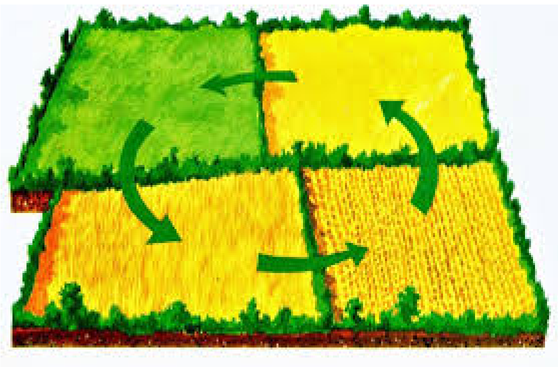

Figure 9 – Crop rotation scheme

To understand why crop rotation is so advantageous, we can think about what happens when we repeatedly cultivate the same crop on the same plot of land (monoculture farming). Monoculture cultivation leads to the extraction of the same nutrients from the soil until they are completely exhausted. The root system of monoculture crops always exploit the same soil layers. Moreover, pests and diseases proliferate more easily and quickly if their favourite crop is guaranteed. Additionally, weeds become more specific for monoculture and, therefore, more resistant. Also, any toxic substances naturally produced by plants accumulate in the soil. For all of the above-mentioned reasons, the practice of monoculture, common in conventional agriculture, requires the use of external synthetic inputs such as synthetic chemical fertilizers and pesticides.

The agronomic practice of rotation involves the planting in succession of at least two main groups of crops:



**1. Improving crops:** crops that increase the fertility of the soil, enriching it with nutrients. For example, legumes, such as alfalfa or clover, are able to transfer nitrogen to the soil from the atmosphere.

**2. Worsening crops:** crops that exploit the nutrients present in the soil and deplete it. These include grain cereals such as wheat, oats, barley, rye, rice, maize and sorghum.

To respect the biological balance of the soil and guarantee fertility, it is recommended to implement many rotations with alternating crops that differ in terms of botanical family, nutritional needs, root systems and farming operations. In the agroecosystem, cereals form an essential component, contributing to the balance of crop rotation.

Figure 10 – Cover cultures composed of Graminandae and Leguminosae

Figure 11 – Chopping of a green manure

The inclusion of green manure in the crop rotation between the two principle crops constitutes good practice. Green manure involves the cultivation of either a pure species or a mixture, not for productive purposes but to be chopped and incorporated into the soil (Figure 11). This practice has the advantage of improving the chemical-physical characteristics of the soil, and in ensuring that the soil remains covered between two main crops. In turn, soil coverage reduces erosion and nutrient leaching processes, and serves to control the development of weeds.

# 3. THE RESILIENT CROPS



## MILLET: Origin, diffusion, varieties and uses

Figures 12 – Common millet

The term «Millet» is commonly used to define a wide range of small cereals, similar in terms of seed size and in the use of grains. All millets belong to the family *Gramineae* and include the genera *Panicum*, *Setaria, Echinocloa*, *Pennisetum* and *Eleusina*. *Panicum miliaceum* (Proso millet or common millet – Figure 12) and *Setaria italica* (Foxtail millet, Italian millet or panic) have been cultivated historically in Italy and are the most well-known.

Millets are particularly drought tolerant plants with a short crop cycle, and can be grown almost anywhere. In some regions of Asia and Africa they represent the main crop, guaranteeing the livelihood of millions of people. The uses of these cereals are numerous and the vast majority can be grown both for fodder and grain production, both for human food or animal feed. Currently, in Italy, millet is known and mainly used as birdseed. Given its excellent nutritional characteristics and high digestibility, it could be reintroduced into the human diet. In general, millets are highly nutritious. The grain consists largely of complex carbohydrates, proteins and unsaturated fats. The presence of slowly digestible starch, together with fibre and polyphenols, renders millet a useful food for keeping both blood sugar and cholesterol under control. It is rich in minerals (iron, magnesium, potassium, zinc, phosphorus, calcium) and B vitamins. The presence of phytates, considered anti-nutritional factors, can be reduced by soaking, sprouting, fermentation and cooking. Like tannins, phytates also have antioxidant properties. An important characteristic of millet is the extended shelf life of the grain, superior to that of other cereals. Millet does not contain gluten and can, therefore, be consumed by both celiac and gluten sensitive people. Millet can be found on the market in the form of hulled grain, semi-wholemeal flour or flakes. The grains do not need to be soaked, but they must be washed well before use in order to eliminate traces of saponins that give the characteristic bitter taste. There are also plant-based beverages made from millet.

## SORGHUM: Origin, diffusion, varieties and uses

Figure 13 – Grain sorghum

Sorghum is a cereal belonging to the *Gramineae* family, originally from Africa and cultivated for millennia (Figure 13). Today it is the fifth most cultivated cereal in the world, with over 40 million hectares, after wheat, rice, corn and barley, respectively. Moreover, there are more than 7,000 different varieties. Sorghum is present on all continents, in tropical and temperate areas, and is also a well-adapted to arid and dry climates. Due to its efficiency and thriftiness in the use of water resources, it is also known as the "camel plant". Sorghum contains a physiological mechanism, able to slow down metabolism in the event of intense water stress to preserve the tissues.

Just over 40% of sorghum production is destined for human consumption, mainly in the semi-arid regions of the world. This is particularly evident in Africa and Asia, where it is consumed in the form of grains (cooked like rice), or semolina and flour (gluten-free) or, after processing, in the form of sugar. Alternative uses involve malting and fermenting for the preparation of beer or other alcoholic beverages.

In contrast, in western countries, sorghum is grown mainly for the production of animal feed, especially attributable to the higher protein content compared to maize. However, the organoleptic and dietary virtues of sorghum are currently being rediscovered in Europe. In fact, it is an excellent source of macro- and micronutrients. The grain is predominantly composed of complex carbohydrates, proteins and unsaturated fats, and also provides a good supply of minerals (phosphorus, iron, magnesium, potassium and zinc) and B vitamins. Additionally, sorghum contains various groups of polyphenols, including phenolic acids, tannins and flavonoids, which provide sorghum with antioxidant, anti-inflammatory and prebiotic properties. Moreover, the fibre and phytosterol content render sorghum a useful food in controlling blood sugar and cholesterol. It should be remembered that tannins, in addition to being powerful antioxidants, also have anti-nutritional effects as they reduce the absorption of starch, proteins and minerals. For this reason, the white varieties, with a reduced tannin content, are preferred for food consumption. An interesting aspect of sorghum is that it is gluten-free and can, therefore, also be consumed by celiac and gluten-sensitive people.

# 4. CULTURAL TECHNIQUES

## MILLET CULTIVATION

### PEDOCLIMATIC REQUIREMENTS AND BIOLOGICAL CYCLE

Millet is a warm-temperate climate cereal and, therefore, requires high temperatures throughout the production cycle. In particular, germination takes place at a temperature of about 11-12 ° C and for this reason it is cultivated in the summer in our areas.

The remarkable rusticity and adaptability of this cereal can be summarized from the following characteristics:

- biological cycle (about 3 months), shorter than other cereals grown in this area
- resistance to drought
- marked earliness which permits cultivation at higher latitudes, given the recent summer temperature increases
- cultivable on a wide variety of soils



### SOIL PREPARATION AND SOWING OF SEEDS

For the cultivation of millet, an alternative mechanism to plowing is implemented. This is because the root system of this cereal is very superficial and would not benefit from plowing operations. The subsequent refinement in working operations must be carried out with care given the small size of the seed. These operations can be well managed with a harrowing step (spike harrow or disc harrow).

Sowing can be performed from late spring to early summer (with a soil temperature of least 13 ° C), using at least 30-35 kg/ha of seed. The seed is usually sown with a wheat seeder machine at a distance of 15-20 cm between the rows and at a depth of either about 3-4 cm in humid soil (after rainfall) or about 5-6 cm in dry soil.

Figure 14 – Growth of the second tipping of millet tiller

Millet is not highly competitive with weeds during the first stages of development. Therefore, it is important to ensure a high density when sowing. Later on in the development, at the stage of stem elongation, the high surface coverage and excellent resistance to drought permit it to compete more effectively with weeds.

**CROP CARE + FERTILIZATION (ROTATIONS, FERTILIZATION AND ADVERSITY MANAGEMENT)**

In an organic farm crop rotation scheme, millet is inserted in succession to either an annual legume or to a winter green manure, incorporated into the soil in mid-March. Millet normally does not require fertilization in moderately fertile soils with adequate cultivation precessions. Given that millet is not very demanding from a nutritional point of view, an excessive availability of nutrients could even be counterproductive.

Weed control in the early stages of millet development is advisable for the success of the crop but, given the superficiality of the root system, it is advisable not to intervene with spring tine weeders before the completion of tillering. False sowing is one of the most recommended agronomic weed control practices. False sowing entails carefully preparing the soil, as if sowing were to be carried out, but at a date that is generally 20-30 days earlier. In so doing, the weeds, that would otherwise have grown together with the crop, germinate earlier and can subsequently be mechanically eliminated either with a surface harrowing, or a passage with the spring tine weeder. Hence, a large quantity of weeds can be removed prior to the sowing of the millet crop. Weed monitoring is very useful, as this permits the rational planning of interventions based on actual needs.



Figure 15 – Common millet field. You can highlight the excellent competition with weeds

Millet is susceptible to various plant diseases, including smuts, rusts and bacteriosis. Therefore, it is recommended to adopt preventive agronomic practices that reduce disease incidence. These practices include the use of healthy seeds, more rotations and balanced fertilization treatments. The adoption of more rotations, as well as practices aimed at increasing biodiversity, greatly reduce the risk of disease incidence and infestation by harmful insects. In general, millet is a very tolerant crop towards biotic stresses, much more so than other more widespread cereals.

**HARVEST AND CONSERVATION**

Millet is harvested when the grains formed on the upper half of the panicle are ripe. Millet has the drawback of uneven ripening and quiescent grain. There is the real risk of an early drop of the more mature grain. Therefore, when choosing the harvest time, it is recommended not to wait for the plant to dry out completely.

Threshing commonly takes place in August with wheat combine harvesters. Care is taken to proceed slowly and to cut the stalk close to the ground as much as possible.

Given the uneven ripening, it is advisable to control the humidity of the grain after threshing. If the humidity values exceed 13%, it is necessary to dry the grain with special systems or spread the grain out in well-ventilated rooms by moving it (Figure 16).

Millet in organic farming has a yield of 2-3 t/ha.

Figure 16 – Drying of millet grains

## SORGHUM CULTIVATION

### PEDOCLIMATIC REQUIREMENTS AND BIOLOGICAL CYCLE

Grain sorghum is an annual plant, with excellent photosynthetic efficiency in hot and dry climatic conditions. It adapts well to various types of soil, preferring well-structured and deep soils, but it also performs very well in clay soils.

### SOIL PREPARATION AND SOWING OF SEEDS

Soil preparation does not require excessive care. As with all summer crops, it is beneficial to make sure of an adequate but not an excessive soil moisture level.

Sowing is carried out with a precision seeder (Figure 17), maintaining an optimal inter-row distance between 40 and 60 cm, and with a seed number ranging from 25 and 35 seeds per $m^2$. Even though sorghum it is usually sown with a higher plant density in conventional production, using a lower seeding density can permit improved development and satisfactory yields with a significant reduction in both fertilizer and irrigation inputs.

Sorghum germinates at a minimum temperature of 10 ° C and grows well at temperature exceeding 16 ° C. Usually in Emilia-Romagna it is recommended to sow from the second half of April, allowing for a rapid and homogeneous emergence that facilitates any subsequent weeding operation by row-crop cultivators.

Sorghum seeds are relatively small and must be placed at less than 3 cm deep. The seedbed must be fine to ensure

Figure 17 – Precision tractor and seeder for sowing sorghum in spaced rows

correct soil/seed contact. Hence, it is important to avoid soils that are too coarse soils and deep sowing.

**CROP CARE + FERTILIZATION (ROTATIONS, FERTILIZATION AND ADVERSITY MANAGEMENT)**

In the rotation scheme of the organic farm, sorghum must be inserted in succession to either an annual legume or to a green manure. Normally, sorghum is not in need of additional fertilization treatments. However, good nitrogen availability ensures better yields.

Figure 18 – The inter-row weeding of sorghum is an excellent solution for the control of weeds

Irrigation is usually not necessary in our areas. The only attention that must be paid is at the time of flowering, a period in which sorghum does not show the same tolerance as millet to water stress. Irrigation may be advisable if there is not enough rainfall in July and if drought conditions occurred during spring.

Weed control in the early stages of sorghum development is essential for the best outcome of the crop. False seeding is one of the most recommended weed control agronomical practices. During the crop cycle, before the plants cover the inter-row with foliage, it is possible to intervene with inter-row weeding actions (Figure 18).

Sorghum is a disease and pest resistant crop. Attacks by parasites can occur, but the infection is often contained and does not require intervention. The main diseases that can cause harm to sorghum are cryptogams, in particular caused by fungi belonging to the genus Fusarium. This risk can be reduced by reducing the sowing density.

**HARVEST AND CONSERVATION**

The harvest of sorghum does not require any specific equipment. A combine harvester equipped for the harvest of straw cereals is suitable.

Figure 19 – White grain sorghum field at the waxy ripening stage

Sorghum can be harvested starting from when the grain reaches 30% humidity. In general, as the drying of the kernels is rapid, the harvest takes place at a humidity between 18% and 25%. Harvesting is recommended at the end of August or within the first ten days of September provided the humidity of the grain is less than 20%.

Sorghum grains should be stored below 15% humidity.

Sorghum in organic farming has a yield of 3-5 t/ha.



# 5. GLOSSARY

**AGRICULTURAL ECOSYSTEM**, or **AGROECOSYSTEM**: a system consisting of biotic components, that are animals, plants and microorganisms, conditioned by different environmental parameters (temperature, light and water), which depend on the climate, and characterized by its main function, namely agricultural activity.

**AGRICULTURAL BIODIVERSITY:** "All the components of biological diversity relevant to food, agriculture and all the elements of biodiversity that make up the agroecosystem. Both the variety and variability of animals, plants and microorganisms, on the genetic, species and ecosystem level, which are necessary to support the key functions of the agroecosystem itself, its structure and processes. " From Convention on Biological Diversity (CBD) of 1992 (Rio de Janeiro, 1992).

**ECOLOGICAL RESILIENCE:** the amount of disturbance a system can withstand before shifting to an alternative stability domain (Holling, 1973)

**CONSERVATION AGRICULTURE:** Soil management method, based on three fundamental principles: large rotations, constant soil cover and the reduction of tillage, including no-tillage. It is aimed at improving the physical, chemical and biological characteristics of the soil.

**GREEN MANURE**: Vegetable cover, with one or more species, not for production purposes. Green manure is useful for the agroecosystem for both the beneficial effects on the soil (reduction of erosion, conservation and interring the organic matter) and for agricultural biodiversity (providing shelter for insects useful as bees).

**GREENHOUSE GASES:** By "greenhouse gases" we mean those gases present in the Earth's atmosphere that produce the so-called greenhouse effect. The predominant greenhouse gases, carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$), naturally present in the atmosphere in limited concentrations, have increased significantly over the last century due to human activities. This has intensified the natural greenhouse effect contributing to global warming.

**GREENHOUSE EFFECT:** A natural phenomenon on which the temperature of the earth's surface depends, due to the presence of so-called greenhouse gases in the atmosphere. The phenomenon is termed as such because it simulates what happens in greenhouses, that is, the maintenance of ambient heat. A fraction of the solar radiation that reaches the Earth's surface is re-emitted in the form of infrared rays, that is, thermal energy. Greenhouse gases hinder the escape of infrared radiation and reflect it back to earth, thus maintaining the surface temperature.



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Figure 20 - Millet field

# GREAT LIFE Agriculture

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