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Field Crops

Course handout dedicated to Third Year Bachelor students in

Plant Production

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Academic Year: 2023 - 2024

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Introduction

Introduction

The term "field crops" refers to agricultural crops that are grown on a large scale for various uses, such as human food, animal feed, biofuel production, and industry. Field crops play a crucial role in the global food supply and in the agricultural economy.

Field crops provide a large part of the staple diet for humans around the world. Potatoes and cereals such as wheat, rice, maize, barley, and sorghum are a major source of carbohydrates, fiber, and certain vitamins and minerals. Legumes, such as soybeans, peas, and beans, are an important source of plant protein, essential amino acids, and nutrients.

Field crops are also used to feed livestock, poultry, and other farm animals. Crops such as alfalfa, clover, barley, oats, maize, soybeans, rapeseed, sunflower, and cereal crop by-products are processed into animal feed, such as compound feed and fodder. This feed provides the necessary nutrients for animal growth, productivity, and health, thus contributing to the production of meat, milk, eggs, and other animal products.

Field crops play a major role in the global agricultural economy. The large-scale cultivation of these plants creates jobs in the agricultural sector, from production to processing and marketing of products. Field crops are often traded internationally, which stimulates global trade. Countries that are major producers of field crops benefit from significant economic revenues through agricultural exports.

Field crops are a pillar of global food security. The production and availability of these crops have a direct impact on the ability of nations to feed their populations and to meet the demands of ever-growing populations.

The study of field crops involves acquiring knowledge about the biological characteristics of cultivated plants, their requirements in terms of soil, climate, and agronomic management. This includes aspects such as the selection of suitable varieties, fertilization practices, irrigation, disease and pest control, as well as weed management.

The study of field crops allows for the development of practical skills in crop management, the evaluation of agricultural production systems, and the adoption of sustainable practices. It also allows for the application of scientific and technical knowledge to improve the productivity, quality, and profitability of crops, while minimizing negative impacts on the environment.

Chapter 1: Cereal crops

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1.1. Generalities

FAO estimates of global cereal production from 2014 to 2022 showed that production increased from 2,557.3 to 2,765 million tons (Table 1). Corn is by far the most produced cereal, followed by wheat and rice. These three cereals account for about 90% of global cereal production.

The countries with the highest cereal production in the world are: China, the United States, India, Russia, Brazil, Indonesia, Argentina, France, Ukraine, and Canada (Fig. 1).

Table 1: World cereal production from 2014 to 2022 (FAO, 2023).

Production	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022
Cereals	2,557.3	2,608.0	2,584.5	2,665.0	2,693.4	2,644.9	2,713.7	2,776.8	2,812.2
Wheat	715,3	735,6	737,3	763,4	761,6	731,4	759,7	775,1	778,0
Rice	490,8	490,4	489,0	497,1	499,9	508,1	503,6	517,9	525,5
Maize	1,351.1	1,382.0	1,358.3	1,404.5	1,432.0	1,405.3	1,450.5	1,483.7	1,508.8

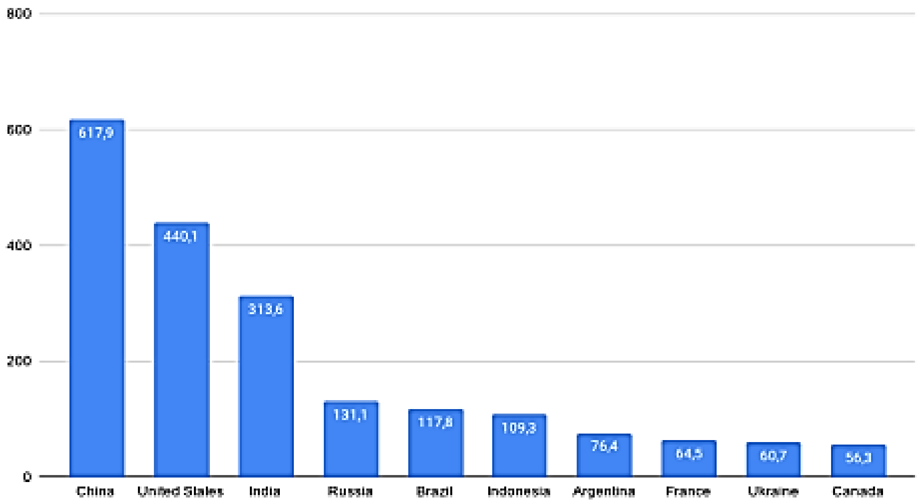

Figure 1: Main cereal producers in the world in 2017 (in millions of tons).
(Source: https://www.indexmundi.com/facts/indicators/AG.PRD.CREL.MT/rankings)

China confirms its first place for rice and wheat production, while it occupies the second position for corn, behind the United States, which asserts itself as the world's leading corn producer.

The countries that consume the most corn are also the main producers, namely the United States and China, followed by the European Union. Regarding wheat, the countries that consume the most are China, followed by the European Union and India. The ranking of the main rice-consuming countries is entirely dominated by the Asian continent: China is ranked first, followed by India and Indonesia. Only the tenth place is occupied by a country outside this geographical area, Brazil (Fig. 2).

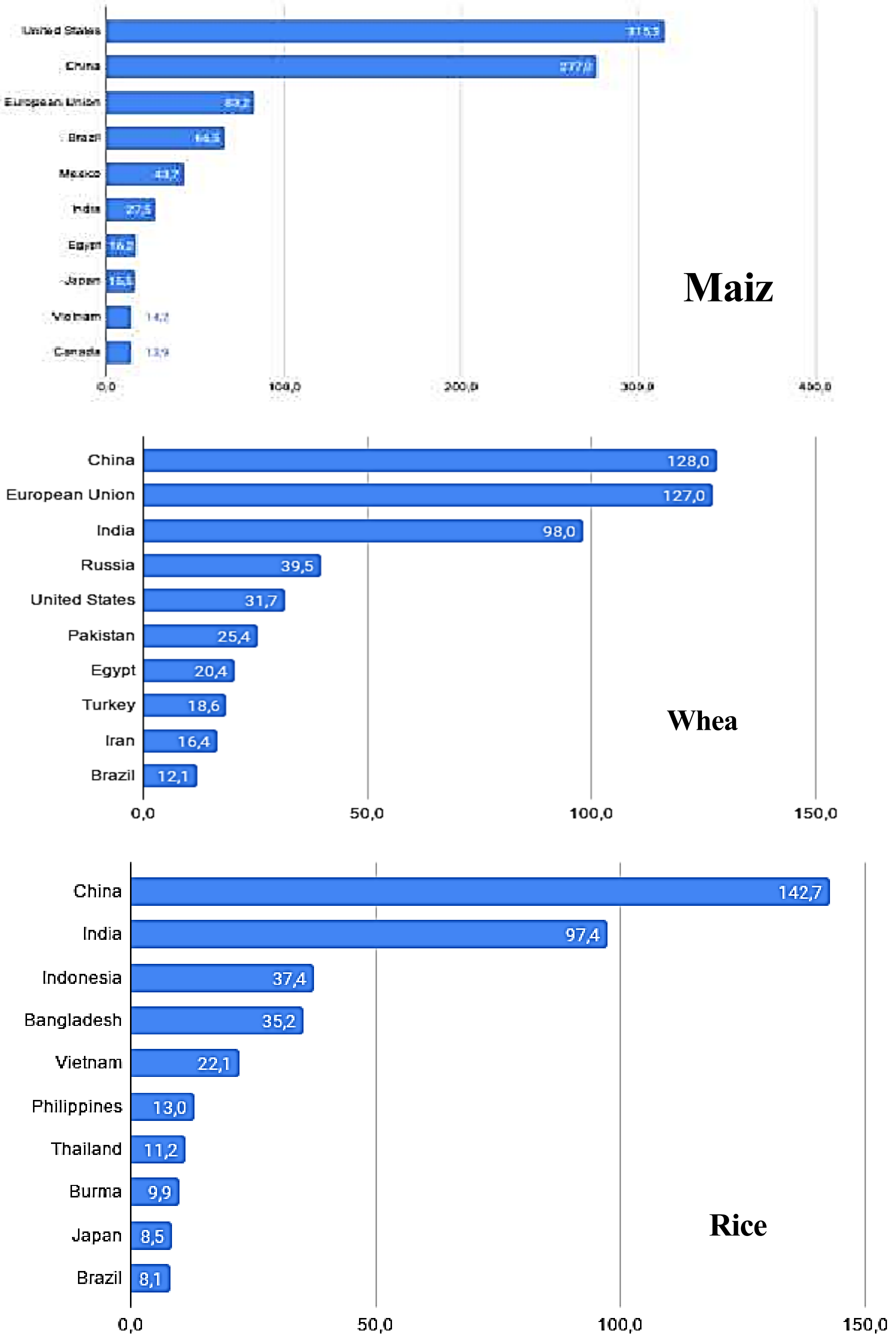

Figure 2: Main cereal consumers in the world in 2019 (in thousands of tons). (Source: https://www.worldatlas.com/articles.html)

Cereals and their derivatives constitute the staple food in many developing countries. In Algeria, cereal products occupy a strategic place in the food system and in the national economy. The area sown annually with cereals is between 3 and 3.5 million ha.

Cereal production in Algeria during the 2017/2018 agricultural season was marked by a significant production estimated at 60.57 million quintals of all categories of cereals combined, compared to 34.7 million quintals recorded during the 2016/2017 agricultural season.

Winter cereal production is divided between durum wheat (31.8 million quintals), barley (19.6 million quintals), common wheat (8 million quintals) and oats (1.18 million quintals). For summer cereals, production reached 91,340 quintals, with a very high production of corn (55,125 quintals).

The cereal processing industry occupies a "leading" position in the agri-food industry sector, due to its significant crushing capacities; (+230%) compared to the size of the domestic market, divided between public (95%) and private (135%) mills, representing a crushing capacity of around 19,000 and 27,000 T/day respectively.

The consumption of cereal products is at a level of approximately 205 kg/person/year. Cereals and their derivatives constitute the backbone of the Algerian food system, and they provide more than 60% of the caloric intake and 75 to 80% of the protein intake of the diet.

In relation to the world market, cereal products represent more than 40% of the value of food imports. Cereal products occupy the first rank (39.22%), ahead of dairy products (20.6%), sugar and confectionery (10%) and oils and fats (10%).

1.2. Definition and origin of cereals

Cereals are species cultivated for their grain. They contain a starchy endosperm. Ground into flour, it is consumable by humans and/or animals.

Most cereals belong to the Poaceae family. The main cereals are: wheat, barley, oats, rye, maize, rice, millet, and sorghum.

Cereals constitute 45% of the energy intake in the human diet. Their organized use is at the origin of civilizations. There are three groups of major cereals which account for 75% of world cereal consumption.

During the very long period preceding recorded history, humans grouped in small nomadic tribes sought above all to survive. The search for food was the essential preoccupation. This came from gathering and hunting. Protection against hostile physical and biological elements was also a major concern.

- A first major group of cereals is formed by wheat, barley, rye, and oats (Fig. 3). It emerged in the Fertile Crescent, the cradle of Western civilizations, which therefore have their starting point in the Middle East and Near East. The Fertile Crescent, from which the cereals of the first group originate, forms an area straddling Africa and Asia. It is centered on the alluvial plains of the Nile in the west, the Jordan in the center, and the Euphrates and Tigris in the east. It is bounded to the west by the Libyan Desert and the Mediterranean Sea, to the north by the Taurus Mountains in Turkey, to the east by the Zagros Mountains in Iran, and to the south by the Red Sea and the Arabian Desert. The oldest known concentrations of cereals resulting from agricultural practices were identified during archaeological excavations in 10,000 BC in Jericho, Jordan. These are non-brittle wheats (einkorn and emmer) and barley (two-row barley).

Wheat **Spelt** **Barley** **Rye** **Oats**

Figure 3: Origin of wheat and some ancient varieties of cereals

- A second major group is formed by maize. It is native to Central America. It is the basis of Amerindian civilizations. Maize was imported into Europe by explorers of the New World at the end of the 15th century.
- A third major group is centered around rice. It is a plant native to the hot and humid regions of Southeast Asia. Its domestication occurred synchronously with the domestication of wheat further west. Rice is the basis of Eastern civilizations.

1.3. Varieties cultivated in Algeria

- ***Durum Wheat***: El Beliouni, Mohamed Ben Bachir (*Gaviota durum*), Bidi 17, Hedba 3, MBB 8037, Oued Zenati 368, T Polo/ZB, Inrat 69, Cocorit 71, MtPellier, Ziban, Capeiti 8, Gloire Mt G., Mexicali75, Guemgoum, Sahel 77, Vitron, Waha, Chen'S, Ardente, GTA dur, Hedba03, Simeto, Cirt, Ofanto, Boussalem, Megress, Amar06, etc.
- ***Common Wheat***: Karim, Mahdia, Azam, Oued Zenati.

- ***Barley***: Saïda183, Rihane, Tichedrette, Jaidor (Dahbia), Barberousse (Hamra), Ascad 176 (Nailia) and El-Fouara.
- ***Triticale***: Meliani, Chélia, Babor and Ifri

1.4. Composition of Cereal Grain

Considering the whole grain of various cereals, we observe a great analogy in their chemical composition but also some differences (Table 2).

Table 2: Composition of cereals (per 100 g of grain at 10% moisture).

Components	Units	Wheat	Sorghum	Millet	Maize	Brown Rice
Proteins	g	13	11	10,6	9,5	8,3
Lipids	g	1,8	3,2	4,1	4	1,6
Carbohydrates	g	61,6	59,3	73,2	66	75
Fibers	g	11	14,5	/	9	4
Calcium	mg	60	26	22	16	22
Phosphorus	mg	312	330	286	220	250
Iron	mg	7,6	10,6	20,7	3,6	2
Vitamin B1	mg	0,35	0,34	0,3	0,33	0,36
Vitamin B2	mg	0,12	0,15	0,22	0,1	0,06
Vitamin PP	mg	6,1	5,3	4,7	3,1	7
Vitamin B6	mg	0,5	/	/	0,4	0,67
Pantothenic acid	mg	0,8	1,2	1,25	0,65	1,7
Biotin	mg	7	/	/	6	12

- ✓ In all species, the grain is essentially carbohydrate-based with 60 to 75% digestible carbohydrates (mainly starch). Cereals thus appear as essentially energy-providing foods: 330 to 385 kcal/100 g.
- ✓ The dietary fiber content is variable (2 to more than 30%).
- ✓ The protein content varies from 6 to 18% in extreme cases but is most often between 8 and 13%.
- ✓ Lipids are relatively scarce but they are extremely interesting due to the high proportion of polyunsaturated fatty acids.
- ✓ Cereals are low in minerals: the phosphorus content is high, the calcium content is low. The Mg, Zn, and Fe contents are also low.
- ✓ With the exception of yellow corn and certain millets that contain active carotenoids, cereals do not have vitamin A activity. Vitamin C is also lacking. The germs are rich in vitamin E. B vitamins are present (with the exception of vitamin B12).

2. Morphological Characters

Cereals are a group of plants belonging to the Poaceae family (formerly called Gramineae). The morphological characteristics of the different cereal species can vary slightly, but all share common characteristics due to their classification in the same plant family. They are characterized by the following morphological characters:

- The leaves are long, narrow, and generally linear, with sheaths that wrap around the stem.
- The stems are hollow and cylindrical, with nodes at regular intervals.
- The flowers are small and arranged in spikes or panicles, with spikelets containing the male and/or female reproductive organs.
- The seeds are small, generally oblong or rounded, and develop in the spikelets.

2.1. The Grain

The cereal grain is a particular achene, called a caryopsis. It results from the transformation of the gynoecium. It is composed of three main parts: the bran, the endosperm (albumen), and the germ (embryo) (Fig. 4):

→ The bran is the hard, fibrous outer layer that protects the grain. It is composed of several layers of hard and fibrous tissues (pericarp, testa, and the aleurone layer). It is mainly composed of cellulose, lignin, and hemicellulose, which give it a fibrous texture and mechanical resistance. The bran also contains nutrients such as vitamins, minerals, and antioxidants, as well as phytochemicals beneficial to health. This is why bran is considered an important part of the human diet.

→ The endosperm is the central part of the cereal grain, which represents the major part of the grain's volume. It is composed mainly of starch, proteins, and small percentages of lipids, minerals, and vitamins. The endosperm is where starch is stored in cereal grains and it serves as an energy source for the germination and growth of the new plant.

→ The germ is the innermost part of the cereal grain, located at the opposite pole from the embryonic shoot. The germ is rich in nutrients such as fats, proteins, vitamins, minerals, and antioxidants. It is the part of the grain that can germinate to produce a new plant.

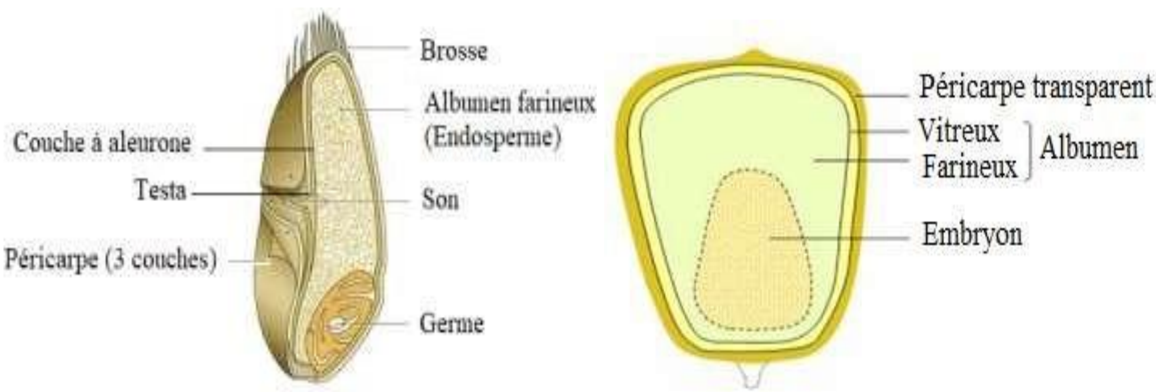

Figure 4: Structure of a cereal grain

During grain germination, the first root and the stem embryo are enclosed in a sheath: this is the coleoptile for the stem and the coleorhiza for the root, which disappear quickly. Many experiments in plant biology use them for the study of plant growth hormones.

2.2. The Vegetative System

The vegetative system of cereals includes the parts of the plant that are responsible for photosynthesis and the production of food for the plant. The vegetative system of cereals is essential for the growth and development of the plant (Fig. 5A). The main parts of the vegetative system of cereals include:

- ***The roots***: Cereal roots are generally fibrous and shallow, extending horizontally from the base of the stem (Fig. 5B). The primary roots (Fig. 5C) of cereals are formed from the embryo, while the adventitious roots (Fig. 5D) are formed from the stem nodes. Adventitious roots are more important than primary roots in the absorption of nutrients and water, and they develop more in response to dry or compact soil.
- ***The stems***: Cereal stems are hollow and cylindrical (Fig. 5E), with nodes at regular intervals (Fig. 5F). They provide structure for the plant, transport water and nutrients from the roots to the leaves, and support the grain heads. The stems of cereals are capable of supporting the weight of the grain heads, which can be heavy. For this reason, cereal stems are relatively rigid and resistant.
- ***The nodes***: The nodes are stem structures where the leaves and grain heads are attached (Fig. 5G). They are also important for the transport of water and nutrients within the plant.
- ***The leaves***: Cereal leaves are long, narrow, and generally linear (Fig. 5H) with parallel venation (Fig. 5I). They have a highly developed leaf base called a sheath. This sheath surrounds the stem in a more or less split cone shape and extends over the entire length of the internode, with the blade becoming distinct at the next node. The ligule (Fig. 5J) is characteristic of cereals; it allows one to distinguish between different cereal species. In some species, it is well-developed, toothed or not, small in other species, and absent in others. Stipules are a kind of bract (Fig. 5K) at the base of the leaves and surrounding the ligule; if present, they are two in number and of highly variable size depending on the species. In barley, they are very developed and clasping.

Figure 5: Vegetative apparatus in cereals

2.3. The reproductive system

Cereals have reproductive organs called spikes or panicles. A spike is a cylindrical structure, composed of axes and bracts arranged in a spiral, on which the spikelets are inserted (Fig. 6). Cereal spikes can be erect or drooping, and they can vary considerably in size and shape depending on the species. A panicle, on the other hand, is a more complex and often more branched structure than the spike (Fig. 7). It consists of a main axis with secondary branches, each bearing spikelets. Panicles are usually found at the end of the stems, and can be cylindrical, conical, pyramidal, or cluster-shaped. Panicles are often larger and looser than spikes, and can be very decorative.

Figure 6: Cereal spikes

Figure 7: Cereal panicles

Spikelets (often three-flowered) are the reproductive structures of cereals, which contain the reproductive organs of the plant. They are arranged on the spike or panicle of the plant and are often protected by leaf-like structures called glumes and lemmas (Fig. 8).

Cereal spikelets can vary considerably in size, shape, and number depending on the species. They can be simple or compound, and can contain several flowers or seeds. Each spikelet generally contains several reproductive organs, including bisexual flowers, which contain both male and female organs. The male organs consist of stamens, which produce pollen, while the female organs consist of pistils, which contain the ovules.

When the spikelets are pollinated, pollen grains land on the stigma of the pistil and begin to germinate, forming a pollen tube that penetrates the ovule of the ovary. This leads to the fertilization of the ovule and the formation of the cereal grain.

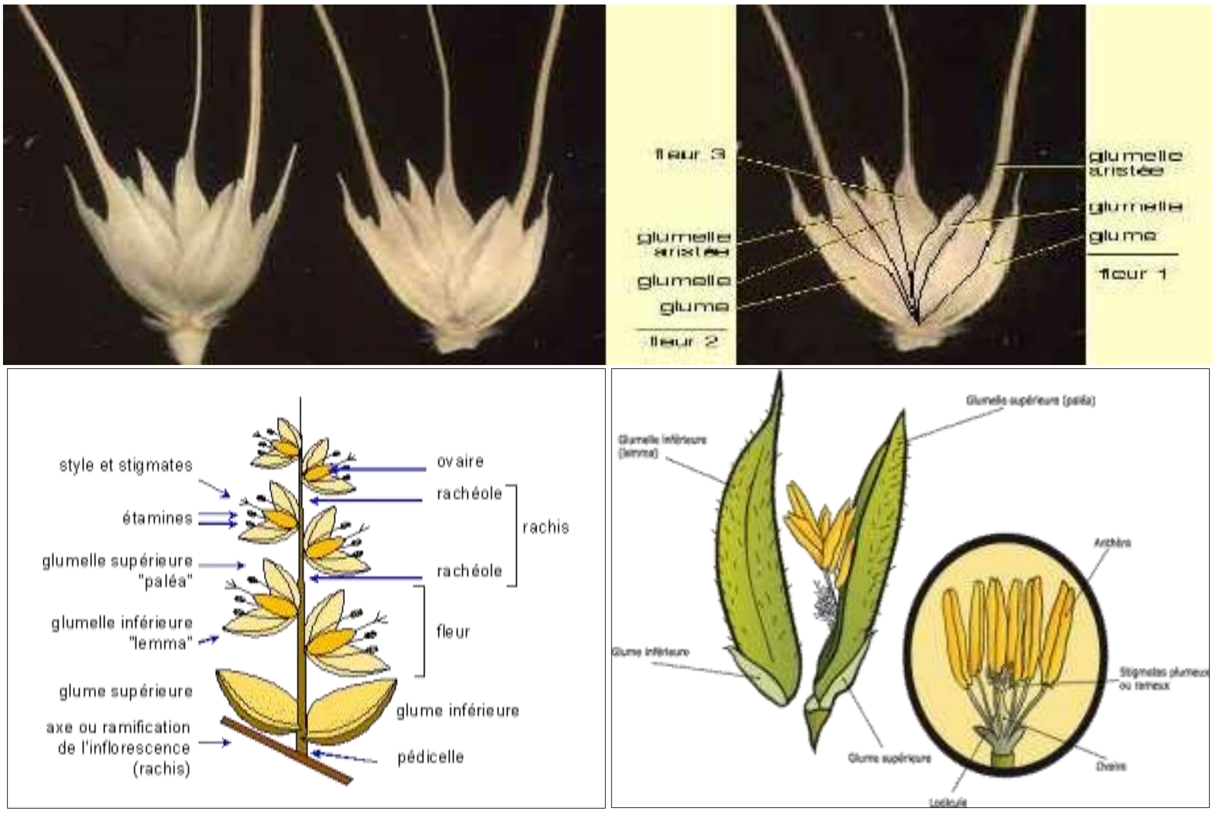

Figure 8: Structure of cereal flowers

3. Biological characteristics

3.1. Description of the development cycle

The cereal development cycle is a complex process that begins with seed germination and ends with grain maturity and harvest. This cycle includes three main periods: the vegetative period, the reproductive period, and the maturity period.

3.2. Vegetative period

The vegetative cycle of cereals includes several important stages, which are:

→ ***Germination***: Germination is the first stage of the cereal life cycle, where the seed begins to sprout and emits a radicle, which will become the roots. This stage is activated by moisture and heat in the soil.

→ ***Emergence***: Emergence is the phase where the sprout emerges from the ground, it is visible to the naked eye. This phase is important because it allows for the evaluation of the emergence success rate and the seedling density.

→ ***Tillering***: The tillering phase begins after emergence. The plant develops several stems that grow horizontally and produce leaves.

→ ***Stem elongation***: Stem elongation is the transition phase between the vegetative growth and the reproductive phase of the plant. During this phase, the plant stems lengthen and straighten.

→ ***Swelling***: Swelling is the process by which a swelling of the stems is observed, from the base upwards, thus allowing the ears to rise to the top of the stem. This phase ends when the awns appear at the top of the stem, indicating the beginning of the next phase.

3.3. Reproductive period

The reproductive cycle of cereals is a complex process that involves several key stages. The main stages of the cereal reproductive cycle are:

→ ***Heading***: Heading is the phase where the plant produces ears. This phase is characterized by the formation of reproductive structures called spikelets. The spikelets contain reproductive organs that produce pollen and ovules.

→ ***Flowering***: Flowering is the reproductive phase of cereals, which occurs after heading.

→ ***Pollination***: Pollination is the process by which pollen from one plant is transferred to the stigma of another plant. In the case of cross-pollinating cereals, pollination is often carried out by the wind, although some species can also be pollinated by insects. In the case of self-pollinating cereals, the pollen of a flower fertilizes the ovules of the same flower.

→ ***Fertilization***: Fertilization is the process by which pollen combines with the ovule of the flower to produce a seed. Fertilization occurs inside the spikelet, where the male and female reproductive organs meet and combine.

→ ***Grain development***: After fertilization, the grains develop and begin to store nutrients for their future growth.

→ **Maturity period:** Cereal maturation is the final phase of their development cycle, during which the grains develop and store food reserves for their future growth. This phase is marked by the maturity of the grains and the senescence of the parts of the plant that are no longer useful. Cereal maturation is a complex process that can vary depending on the species of cereals and environmental conditions. However, in general, cereal ripening includes the following stages:

- → ***Grain Filling***: The grains begin to fill with sugars, starches, and other nutrients from the plant. This stage is crucial for grain quality and yield.
- → ***Senescence of Plant Parts***: The parts of the plant that are no longer useful begin to dry out and die. The stem and leaves turn yellow and begin to bend, indicating that the plant is entering the maturity phase.
- → ***Grain Hardening***: The grains begin to harden and dry, making them more resistant to shattering or rotting.
- → ***Color Change***: The color of the grains begins to change, from a green or milky color to a golden or brown color, depending on the cereal species.
- → ***Physiological Maturity***: This is the stage where the grain has reached its maximum weight and minimum moisture content, meaning it is ready for harvest.

The typical stages of cereal ***grain ripening*** are as follows:

- ✓ **Milky**: At this stage, the grains are still white or pale yellow and are filled with a white, milky liquid substance. They contain about 80% moisture.
- ✓ **Dough**: The grains transition from the milky stage to the dough stage, where the substance inside the grain becomes thicker and more viscous. The moisture content of the grains decreases to about 70%.
- ✓ **Ripe**: The grains become firmer and the moisture content decreases further. They also begin to take on a darker color, ranging from pale yellow to brown, depending on the cereal species.
- ✓ **Mature**: The grains reach their maximum size and weight and their moisture content drops to about 10 to 15%. The color of the grains continues to darken and most cereal plants dry out and begin to die.

- ✓ **Overripe**: If the grains remain on the plant after maturity, they can become too dry and lose quality. At this stage, the grains are vulnerable to lodging (falling of the ears) and degradation by molds and pests.

Farmers must carefully monitor the ripening process to determine the best time for harvest. If the harvest is too early, the grains will not be fully developed and the yield will be low. If the harvest is too late, the grains may be affected by unfavorable weather conditions or be damaged by diseases or insects. Therefore, harvesting should be carried out when the grain moisture content is optimal to ensure high quality and yield.

Physiological maturity can be determined by observing the color of the grains, which changes from green to a darker, drier color, such as golden or brown. The grains are also harder at this stage, making them more resistant to damage during harvesting and storage.

Grain moisture content is also an important indicator of physiological maturity. The grain must reach a specific moisture content to be harvested and stored effectively. In general, the optimal moisture content for harvesting cereals is between 12% and 14% for wheat, barley, oats, rye, and corn. For rice, the optimal moisture content for harvesting is generally between 18% and 20%. If the grain is harvested too early, it may contain too much moisture, which can lead to quality loss and contamination by molds and fungi. If the grain is harvested too late, it may be more vulnerable to physical damage and pest attacks.

4. Technical Itinerary

The technical itinerary for cereal crops includes several stages, including the choice of cropping system, soil preparation, sowing, irrigation, fertilization, protection against diseases and pests and weed control, as well as harvesting.

4.1 Choice of Cropping System

The choice of cropping system for cereals depends on local conditions, such as soil type, climate, and water availability. Common cropping systems for cereals include monoculture, crop rotation, intercropping, and cover cropping.

There are different cropping systems for growing cereals, depending on local agricultural practices and environmental conditions. Among the cropping systems and previous crops that can be used for cereal cultivation are:

- ***Crop Rotation System***: In this system, crops are grown in rotation on the same plot of land, so as to avoid soil depletion and reduce the pressure of diseases and pests. Cereal crops are often grown in alternation with legumes, which fix nitrogen from the air into the soil and improve its fertility. Legumes are also rich in organic matter, which improves soil structure and its ability to retain water.

- ***Cover Cropping System***: In this system, cereals are grown under a plant cover, such as clover or alfalfa, which is sown before or after the cereal crop and remains in place for several months. The plant cover protects the soil from erosion, improves its fertility and structure, and reduces weed competition.
- ***No-Till Farming System***: In this system, cereals are sown directly into the soil without tilling or turning the soil. This practice preserves soil structure and biodiversity, while reducing fuel consumption and greenhouse gas emissions associated with tillage. Cover crops can be used to improve soil fertility and structure.

Regarding previous crops, the following crops can be used as predecessors for cereal cultivation:

- ✓ Legumes that fix nitrogen from the air into the soil and improve its fertility.
- ✓ Forage crops, such as corn or sorghum, which provide a significant amount of organic matter and improve soil structure.
- ✓ Cover crops, such as rye, which protect the soil from erosion and reduce weed competition.
- ✓ Spring crops, such as peas or beans, which are sown before winter cereals and help reduce the pressure of diseases and pests.

It is important to choose the cropping system and the previous crop based on the local characteristics of the soil, climate, water availability and resources, as well as the farmer's production objectives.

4.2. Soil Preparation

Soil preparation for a cereal crop can vary depending on local agricultural practices and environmental conditions. The key elements to consider for soil preparation for a cereal crop are:

→ ***Soil Preparation***: The soil must be prepared before sowing. Soil preparation can include several steps, such as plowing, shallow cultivation, harrowing, and rolling. Plowing consists of turning the soil over to a certain depth, while shallow cultivation, harrowing, and rolling level the soil and make it more suitable for sowing.

→ ***Soil Working Depth***: The soil working depth depends on several factors, such as the type of soil, the type of cereal crop, and the presence of weeds. In general, for a cereal crop, the working depth should be sufficient to allow the roots to develop properly, but not too deep to avoid soil depletion and disruption of microbial life.

→ ***Soil Structure Improvement***: Soil structure is important for cereal crops because it influences the availability of water and nutrients for the plant. To improve soil structure, it is recommended to use agricultural practices such as direct seeding, cover crops, intercropping, and the addition of organic matter.

→ ***Weed Control***: Weeds can be a source of competition for cereal crops, using resources necessary for cereal growth. To control weeds, it is recommended to use agricultural practices such as mechanical weeding, the use of mulch and cover crops, as well as the use of phytosanitary products as a last resort.

It is important to note that soil tillage for cereal crops must be adapted to the local characteristics of the soil, climate, water availability and resources, as well as the farmer's production objectives. It is also recommended to use sustainable agricultural practices to preserve soil fertility and biodiversity.

4.3. Sowing

Sowing is an important step in cereal crop cultivation, as it largely determines the yield potential of the crop. The key elements to consider when sowing a cereal crop are:

- ***Sowing Density***: The sowing density depends on the type of cereal, the variety, the growing conditions and the production objectives. In general, the recommended sowing density for soft wheat is around 200 to 300 grains/m², for barley around 250 to 350 grains/m² and for maize around 70,000 to 100,000 plants/ha.
- ***Sowing Depth***: The sowing depth also depends on the type of cereal, the type of soil and the growing conditions. In general, the recommended sowing depth for soft wheat is around 3 to 5 cm, for barley around 2 to 4 cm and for maize around 5 to 6 cm.
- ***Seed Calibration***: Seed calibration is important to ensure a homogeneous sowing density and a uniform distribution of plants in the field. It is recommended to use quality seeds that are regular and well-calibrated.

Fertilization: Fertilization is important to ensure vigorous growth and quality production. The fertilization dose depends on the type of soil, the variety, the growing conditions and the production objectives. It is recommended to carry out a soil analysis to determine the fertilization needs and to adapt the dose according to the results.

- ***Spreading***: Spreading must be carried out uniformly to avoid overdensity or gaps in the crop. For homogeneous spreading, it is recommended to use disc seeders, tine seeders or pneumatic seeders.
- ***Sowing Period***: The sowing period depends on the type of cereal, the climatic conditions and the production objectives. In general, for soft wheat, sowing should be carried out in autumn, between mid-October and early November. For barley, sowing can be carried out either in autumn or in spring. For maize, sowing is carried out in spring, generally in April

or May.

- It is important to note that the sowing rate must be adapted to the local characteristics of the soil, climate, water availability and resources, as well as the farmer's production objectives. Too low a sowing density can lead to poor soil cover and increased competition between plants, while too high a sowing density can lead to competition for resources and a decrease in yield.

4.4. Irrigation

Irrigation may be necessary to maintain soil moisture at an optimal level for plant growth. The timing and amount of water depend on local conditions, such as rainfall and relative humidity.

4.5. Fertilization

Cereals need nutrients to grow, such as nitrogen, phosphorus, and potassium. Fertilization can be carried out using chemical fertilizers or organic amendments, such as manure. The key elements to consider for fertilizing a cereal crop are:

→ ***Soil Analysis***: Soil analysis is the first step in determining the fertilization needs of the cereal crop. It allows you to know the levels of nutrients present in the soil and to adapt the fertilization accordingly.

→ ***Choice of Fertilizers***: There are several types of fertilizers, such as nitrogen, phosphate, and potassium fertilizers. The choice of fertilizers depends on the nutrient needs of the crop, the levels of nutrients present in the soil, and the growing conditions.

→ ***Fertilizer Dose***: The fertilizer dose depends on the nutrient needs of the crop, the soil composition, and the production objective. It is important not to underestimate or overestimate the fertilizer dose, as this can impact the yield and quality of the harvest.

→ ***Timing of Fertilization***: The timing of fertilization depends on the type of cereal crop and the climatic conditions. It is important to fertilize the crop appropriately based on its nutrient needs throughout its development cycle.

→ ***Fertilizer Application***: Fertilizer application can be done before sowing, during sowing, or after sowing, depending on the type of fertilizer used and the needs of the cereal crop. It is important to ensure a homogeneous distribution of fertilizers to avoid excessive concentration of nutrients in certain areas of the field.

→ ***Organic Fertilization***: Organic fertilization can be an alternative or a complement to mineral fertilization. It can be obtained from manure, compost, or other organic matter. Organic fertilization can help improve soil structure and provide nutrients to the crop gradually.

Fertilizer requirements for cereals depend on several factors, such as the type of cereal, soil quality, climate, and desired yield. However, in general, cereals need three main nutrients for vigorous growth: nitrogen (N), phosphorus (P), and potassium (K).

→ ***Nitrogen (N)***: Nitrogen is essential for the growth of leaves, stems, and cereal ears. Cereals need a significant amount of nitrogen to achieve a high yield. The amount of nitrogen required depends on many factors, including the soil's organic matter content, the cereal variety, the sowing density, and the climatic conditions. Straw cereals need about 100 to 150 kg/ha of nitrogen to achieve optimal yield.

→ ***Phosphorus (P)***: Phosphorus is important for the growth of cereal roots and for seed development. Cereals need sufficient amounts of phosphorus to support plant growth. The amount of phosphorus required also depends on the cereal variety and growing conditions. Cereals generally need about 30 to 50 kg/ha of phosphorus.

→ ***Potassium (K)***: Potassium is essential for the growth and development of cereals, particularly for regulating water content and disease resistance. Cereals need sufficient amounts of potassium to achieve optimal yield. The amount of potassium required depends on the cereal variety and growing conditions. Cereals generally need about 80 to 100 kg/ha of potassium.

4.6. Weeding

Weeding is an important step in cereal crop cultivation, as weeds can compete with cereal crops for nutrients, water, and light, which can reduce crop yields. There are several weeding methods for cereal crops, including:

Mechanical Weeding: Mechanical weeding involves using tools such as harrows, cultivators, hoes, and weeders to remove weeds from the soil. This method can be used before or after sowing cereal crops, depending on the type of crop and growing conditions. Mechanical weeding can be effective for annual weeds, but may not be as effective for perennial weeds.

Chemical weeding: Chemical weeding involves using herbicides to kill weeds in cereal crops. Herbicides can be applied before or after sowing the crops, depending on the cereal variety and growing conditions. Herbicides can be applied as a spray or in granular form. This method can be effective for annual and perennial weeds, but must be used with caution to avoid adverse effects on the environment and human health.

Manual Weeding: Manual weeding involves removing weeds by hand. This method is often used on small farms or for organic cereal crops, but can be labor-intensive.

It is important to note that the choice of weeding method will depend on local conditions, the type of crop, and the farming practices used. Farmers should also use herbicides and weeding methods with caution to minimize adverse effects on the environment and human health.

4.7. Pest and Disease Control and Weed Management

Cereals are susceptible to diseases, pests, and weeds that can reduce yield and quality. Crop protection practices include the use of insecticides, fungicides, and herbicides.

Crop protection treatments for cereal crops are used to protect crops from pests and diseases, which can cause significant crop damage and reduce yields. Crop protection treatments can include pesticides, herbicides, and fungicides, which are applied according to the specific needs of the crop.

Pesticides: Pesticides are used to control pests that attack cereal crops, such as insects, mites, mollusks, and nematodes. Pesticides can be applied at different stages of plant growth, depending on the type of pest and infestation. Pesticides can be applied as sprays, drenches, or granules.

Herbicides: Herbicides are used to control weeds that compete with cereal crops for nutrients, water, and light. Herbicides can be applied before or after sowing the crops, depending on the cereal variety and growing conditions. Herbicides can be applied as a spray or as granules.

Fungicides: Fungicides are used to control fungal diseases that attack cereal crops, such as rust, septoria, and fusarium. Fungicides can be applied at different stages of plant growth, depending on the type of disease and infestation. Fungicides can be applied as sprays, dusts, or seed treatments.

It is important to note that crop protection treatments should be used with caution to minimize adverse effects on the environment and human health. It is recommended to use crop protection treatments that are specific to the cereal crop and have been approved for safe and effective use. Farmers should also follow good agricultural practices to minimize the use of crop protection treatments and preserve soil health and ecosystems.

4.8. Harvest

Harvesting should be carried out when the grains have reached physiological maturity and the moisture content is at an appropriate level for storage. Harvesting can be done manually or mechanically.

Harvesting is an important step in cereal crop cultivation, as it allows for the reaping of the fruits of several months of work. The main stages of harvesting for a cereal crop are:

- ***Maturity***: Cereals are ready to be harvested when the grains are ripe and dry. To determine if the grains are ready, farmers often perform moisture content tests.

- ***Combine Harvester Preparation***: Combine harvesters are machines used to harvest cereals. Before harvesting, farmers prepare their combine harvester by checking that all settings are correct and ensuring that the machine is in good working order.
- ***Harvesting***: Once the cereals are ripe, farmers harvest the crops using the combine harvester. The machine cuts the cereal stalks, separates the grains from the straw, and stores the grains in a tank.
- ***Drying and Cleaning***: After harvesting, the grains may be dried and cleaned to remove impurities and damaged grains. Farmers can use grain dryers and cleaning equipment for this process.
- ***Storage***: The grains are then stored in silos or warehouses to protect them from insects, moisture, and other environmental factors. Farmers may use ventilation and cooling equipment to maintain the grains in optimal storage conditions.

Chapter 2: Potato

Chapter 2: The Potato

1. General Information

The potato belongs to the **Solanaceae** family and the **Solanum** genus, which includes several tuber-bearing species. The centers of origin of the potato are believed to be in Mexico and the central region of the Andes Mountains (above 2000 m).

The potato is native to the Lake Titicaca region, domesticated long ago by the Amerindian peoples of southwestern Latin America, which Spanish explorers and conquistadors discovered and brought back to Europe in the 16th century. Europeans gradually acclimatized it and adopted it to the point of making it an essential ingredient in their diet from the 18th century onwards, especially in Northern Europe, from Ireland to Russia.

The potato was one of the factors in the Industrial Revolution before being spread mainly by colonial empires, and also for the necessities of navigation, across all continents. In the 20th century and still at the beginning of the 21st century, it continues its expansion, particularly in Asia and Africa. It has also become the raw material for an agro-food processing industry, both for the production of starch and its derivatives and for the manufacture of industrial foods.

2. Production

2.1. In the world

The potato is one of the most consumed vegetables in the world. It is cultivated in more than 125 countries, with a total annual production of about 388 million tons (Fig. 9). The main potato producers are China, India, Russia, Ukraine, and the United States (Fig. 10).

The potato production area in the world is about 19.2 million hectares. In recent years, potato production areas have shown some stability. The largest potato producers in terms of cultivated area are China, India, Russia, Ukraine, and the United States.

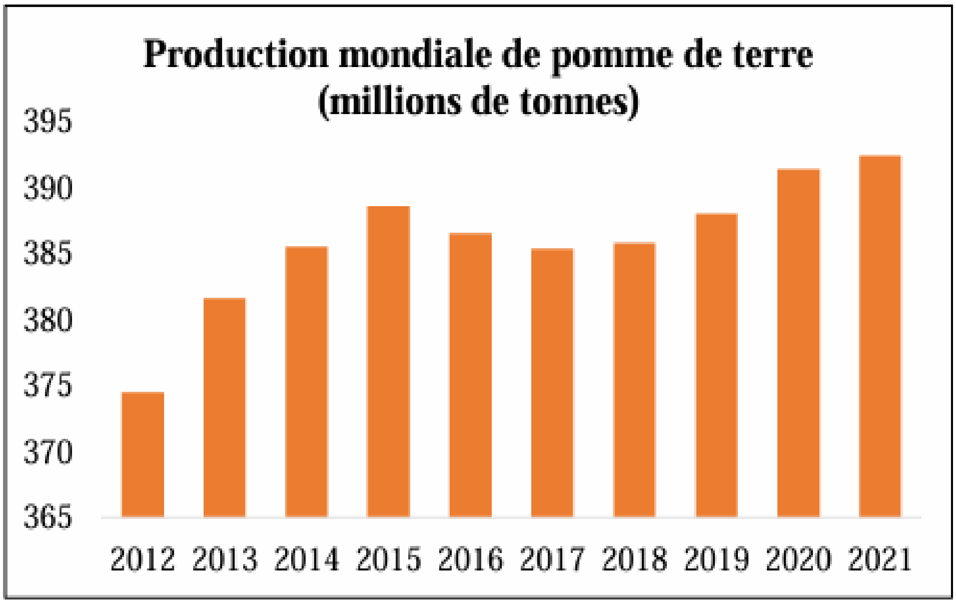

Figure 9: World potato production from 2012 to 2021

Figure 10: Distribution of potato production in 2019 (FAO, 2019).

The top 20 potato producing countries in the world in 2020, according to FAOSTAT data, are shown in Figure (11).

These figures show that potato production is concentrated in a few countries, particularly China and India, which alone account for more than 40% of world potato production.

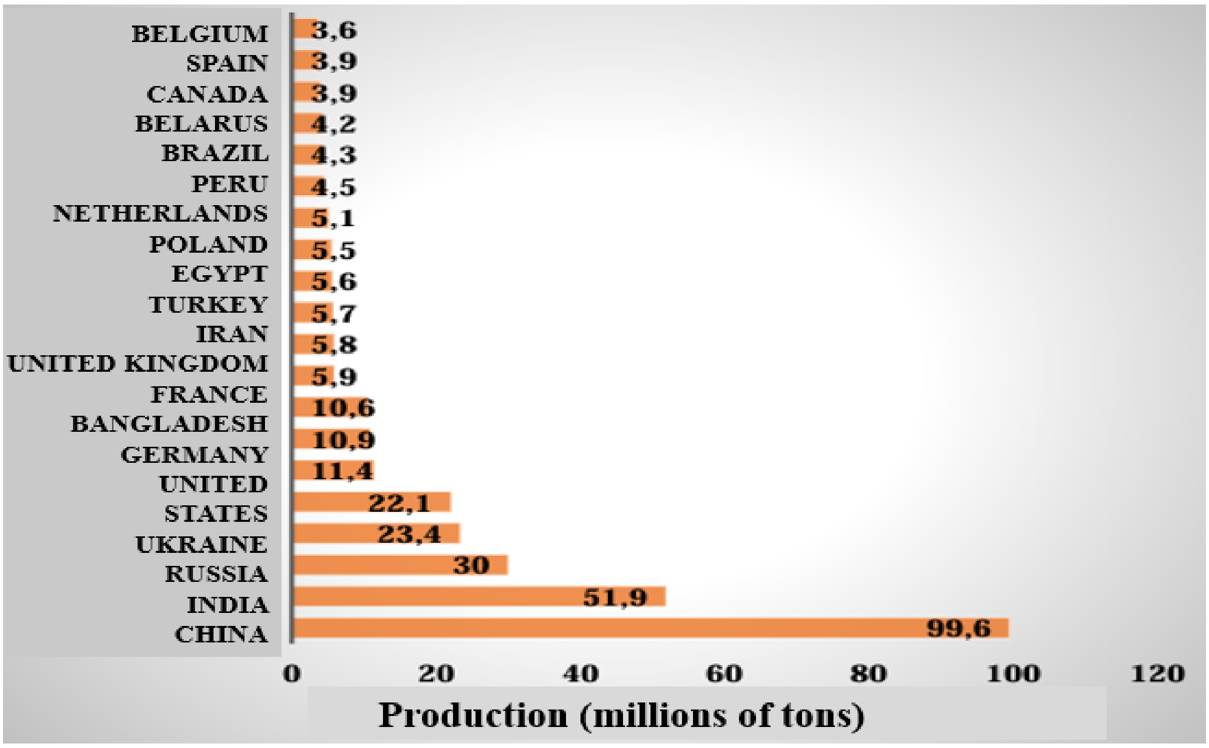

Figure 11: The top potato producing countries in the world in 2020 (FAO, 2020).

2.2. In Algeria

According to FAOSTAT data, Algeria produced about 3.7 million tons of potatoes in 2020, ranking it 25th in the world in terms of potato production. The main potato producers in Africa are Egypt, Algeria, Morocco, South Africa, and Ethiopia. Although potato production in Algeria is relatively modest compared to other countries, the potato is an important crop in Algeria and is widely consumed in the country.

Potato production data in Algeria for the last ten years (Fig. 12), according to FAOSTAT, shows that Algerian potato production has fluctuated over the last decade, with a peak in 2013 (4.8 million tons) and a decline in recent years (3.5 to 3.7 million tons). This may be due to factors such as weather conditions, plant diseases, funding problems or other economic factors. However, potato production in Algeria remains important for the country's agricultural economy.

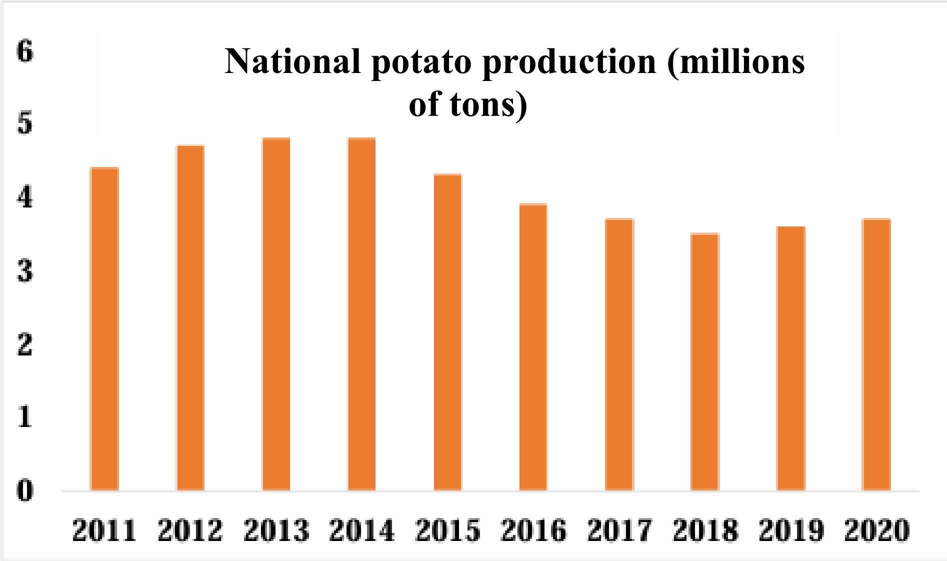

Figure 12: National potato production from 2011 to 2020 (FAO, 2020)

The main potato production regions in Algeria, in 2020, are the wilayas of Sétif, Batna, Tiaret, Tizi Ouzou, Blida, Mascara, El Oued and Ain Defla (Fig. 13).

It is important to note that potato production in Algeria can vary from year to year depending on weather conditions and economic factors. These figures should therefore be taken as a general indication of potato production in each region.

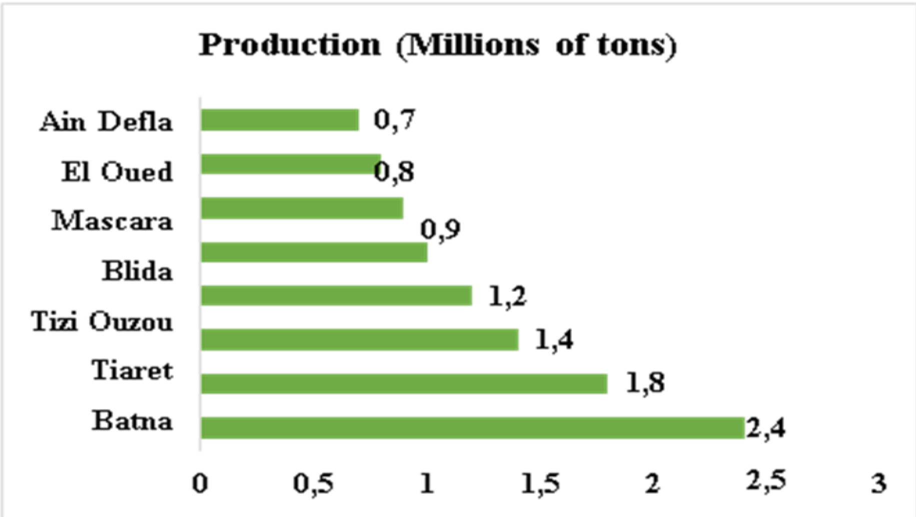

Figure 13: The most productive potato regions in 2020 (FAO, 2020)

The total potato production area in Algeria for the year 2020 was approximately 189,000 hectares, according to data from the Ministry of Agriculture and Rural Development. This represents an increase compared to the previous year, where the total area was approximately 184,000 hectares.

The following table summarizes the potato production areas in the main potato production regions in 2020.

Table 3 : Potato production areas in Algeria for the year 2020 (in hectares) by wilaya.

Regions	Area (ha)
Sétif	43 500
Batna	33 800
Tiaret	26 200
Tizi Ouzou	22 400
Blida	18 500
Mascara	16 700
El Oued	14 800
Ain Defla	12 500

3. Nutritional value of potatoes

The potato is a very nutritious food and is rich in several nutrients important for health. For 100g of raw potato, we find, on average, 77 kcal of calories, 75 to 80% water, 15 to 17% starch, 2% dietary fiber, 2% protein, 0.1 to 0.2% fat, 0.020% vitamin C, 0.003% vitamin B6, 0.421% potassium, 0.023% magnesium and 0.006% iron.

Potatoes are also an excellent source of resistant starch; a type of carbohydrate that can help improve digestive health and reduce the risk of chronic diseases. However, it is important to note that most of the vitamins and minerals are found in the potato skin. Therefore, it is recommended to eat the potato with its skin to benefit from all its nutritional benefits.

4. Distribution of crops and production.

Due to the diversity of growing environments, which results in particular from the differences in altitude between the coastal plains and the inland regions and the influence of the Mediterranean climate, which gradually decreases from North to South, potato plantings follow one another without interruption during the agricultural season from the coastal region inland.

→ ***Early harvest cultivation***: This method consists of cultivating fast-growing potato varieties for an early harvest, generally from May to July. This method is common in warmer regions and allows for an early harvest. Early harvest cultivation is common in the coastal regions of the country, such as the Annaba region, Skikda and Bejaia, where the climate is cooler and more humid. The planting period is generally between January and February for an early harvest in April or May.

→ ***Main season cultivation***: This method consists of cultivating potato varieties that can be planted at the beginning of the season, generally from March to April, and harvested at the end of summer, from September to October. This method is common in temperate regions and allows for a larger harvest than early harvest cultivation. Main season cultivation is practiced in different regions of Algeria, particularly in temperate zones such as the Oran, Constantine and Algiers regions. The planting period is generally between March and April for a harvest in September or October.

→ ***Late season cultivation***: This method consists of cultivating potato varieties that can be planted in summer and harvested in autumn or winter, generally from September to December. This method is common in colder regions and allows for a late harvest for long-term use. Late season cultivation is less common in Algeria, but it is practiced in some cooler regions of the country, such as the mountains of eastern and western Algeria. The planting period is generally between July and August for a harvest in December or January.

5. Botanical characteristics

The potato (*Solanum tuberosum*) is a herbaceous perennial plant belonging to the Solanaceae family.

5.1. Stem

The stem of the potato (*Solanum tuberosum*) is an erect and cylindrical aerial structure that can reach up to one meter in height. It is made up of several segments, called internodes, separated by nodes.

Potato stems are generally branched, producing lateral branches called stems. The stems are shorter than the main stem and bear leaves, flowers or tubers (Fig. 14).

The potato stem is an important structure for the growth of the plant, as it transports water and nutrients from the roots to the leaves and tubers. The tubers are actually modified stems that develop from the nodes of the stem and stolons, creeping stems produced by the plant.

It is important to note that the aerial parts of the potato, including the stems, leaves and flowers, contain glycoalkaloids called solanine, compounds toxic which can be dangerous for human consumption in large quantities.

Figure 14: Potato stem.

5.2. Leaves

The aerial system consists of several leafy stems and branches (as many as the mother tuber has developed sprouts). Each leaf is composed of 3 to 5 pairs of leaflets and a terminal one.

The potato leaves are alternate, simple, and measure between 10 and 30 cm long. They are palmate, meaning they are divided into several leaflets, which are oval to oblong. The leaflets have a toothed margin and a pointed tip (Fig. 15).

Figure 15: Potato Leaf

5.3. Flowers

In the axil of a leaf of the apical bud of the stem (or a branch), in certain varieties, at a certain stage of development, an inflorescence can appear, a biparous cyme that can have 8 to 10 flowers. Self-pollination is almost absolute.

The flowers of the potato are the reproductive organs of the plant. They develop on lateral stems called peduncles, which emerge from the nodes of the main stem. They have a characteristic star shape, with five white or pink petals and a green calyx that protects the developing flower (Fig. 16). The flowers generally measure 2 to 4 cm in diameter and are borne on short stems that branch from the peduncles.

Potato flowers are pollinated by insects, mainly bees. The plant also produces fruits, which are green or yellow berries containing many seeds.

Figure 16: Potato Flowers

5.4. Fruit

The fruits of the potato are globose berries that contain many seeds. The fruits are about 1 to 2 cm in diameter and have a round to oval shape (Fig. 17). Potato fruits can be green or yellow when ripe, depending on the variety. Fruits are rarely produced because cultivated plants are generally grown from tubers. It is important to note that potato fruits are not edible and can even be toxic.

Figure 17: Potato Fruits

5.5. Tuber

The roots of the potato are poorly developed and do not play an important role in feeding the plant.

The tuber represents the swollen end of a stolon (underground stem). Like any stem, it bears, in the axil of aborted leaves (the scales), dormant buds located at the bottom of a depression (the eye), underlined by the very reduced scale leaf (Fig. 18). At the distal end, opposite the mark of the tuber's insertion on the stolon (the heel), the eyes gathered around the terminal bud form the crown. The tubers are round or oval, beige to dark brown in color, and can measure from a few centimeters to more than 10 cm in diameter. They are rich in starch and other nutrients.

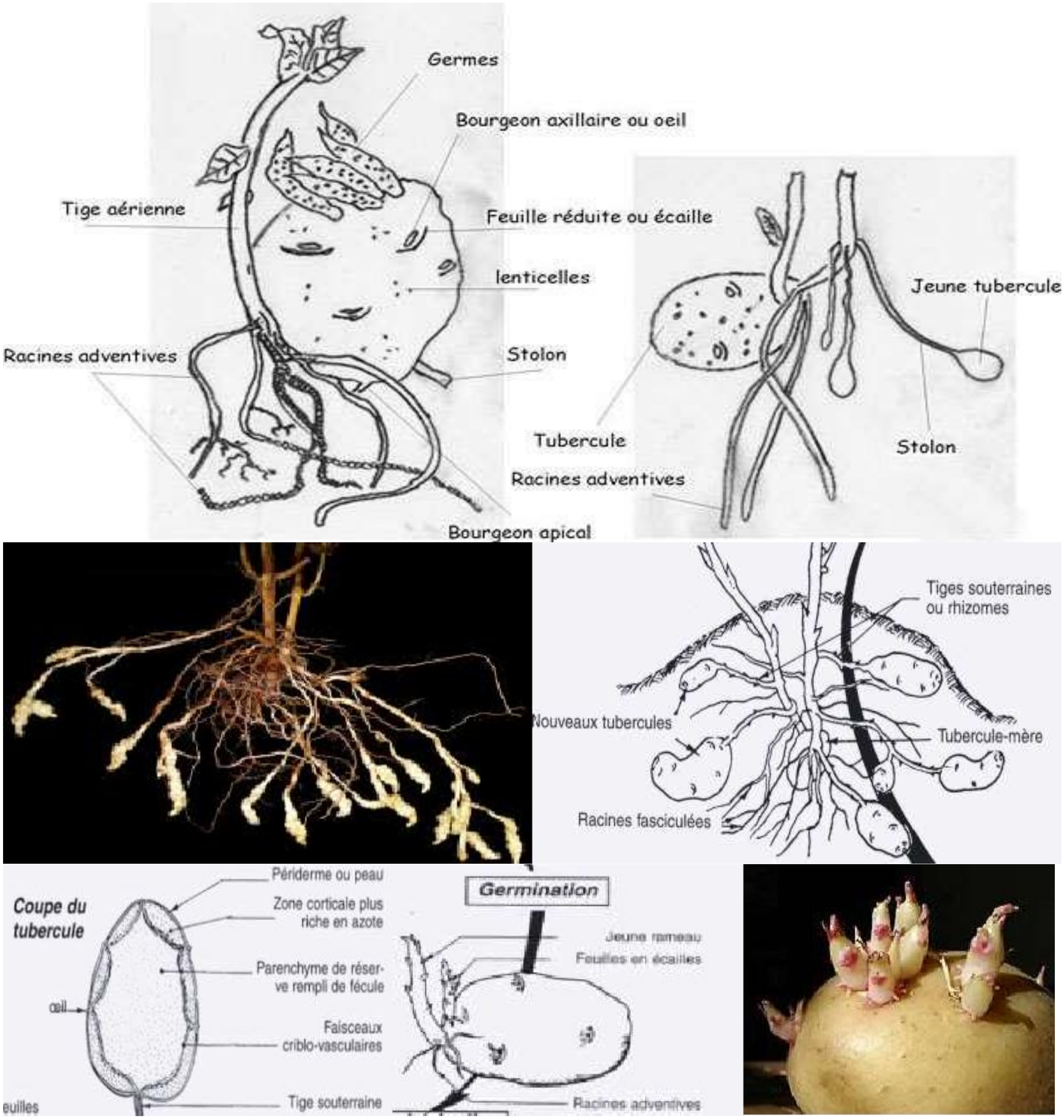

Figure 18: Potato Fruits

After a period of vegetative rest, the buds begin to grow: the tuber sprouts. The sprouts develop by differentiation and elongation of internodes. They bear, like any young branch, leaves; those at the base remain scaly, those at the top will be chlorophyllous and will constitute the future foliage of the adult plant. When this sprout has reached 3 to 4 cm, adventitious roots develop at the base of the scale leaves. Lateral buds give rise to new stolons, which will swell at their ends, forming daughter tubers.

6. Development Cycle

The potato's development cycle can be divided into five main stages: planting, germination, vegetative growth, flowering, and maturation.

- ***Planting***: Potatoes are planted in the ground in early spring, generally between March and May, depending on the climate. The tubers are placed at a depth of 10 to 15 cm and spaced about 30 to 40 cm apart.
- ***Germination***: After planting, the tubers begin to sprout and produce green shoots. These shoots develop from the potato's "eyes" and emerge from the soil surface.
- ***Vegetative Growth***: During this stage, the potato plant develops leaves, stems, and roots. The leaves absorb sunlight and use photosynthesis to produce energy, which is stored in the tubers. This stage lasts about 2 to 3 months.
- ***Flowering***: During the summer, the potato plant begins to produce white or pink flowers. These flowers attract pollinating insects that help fertilize the plant's ovules.
- ***Maturation***: The potato reaches maturity in late summer or early autumn, about 90 to 120 days after planting. The leaves begin to yellow and die, indicating that the tubers are ready to be harvested. The potatoes are then dug up from the ground and stored for consumption or processing.

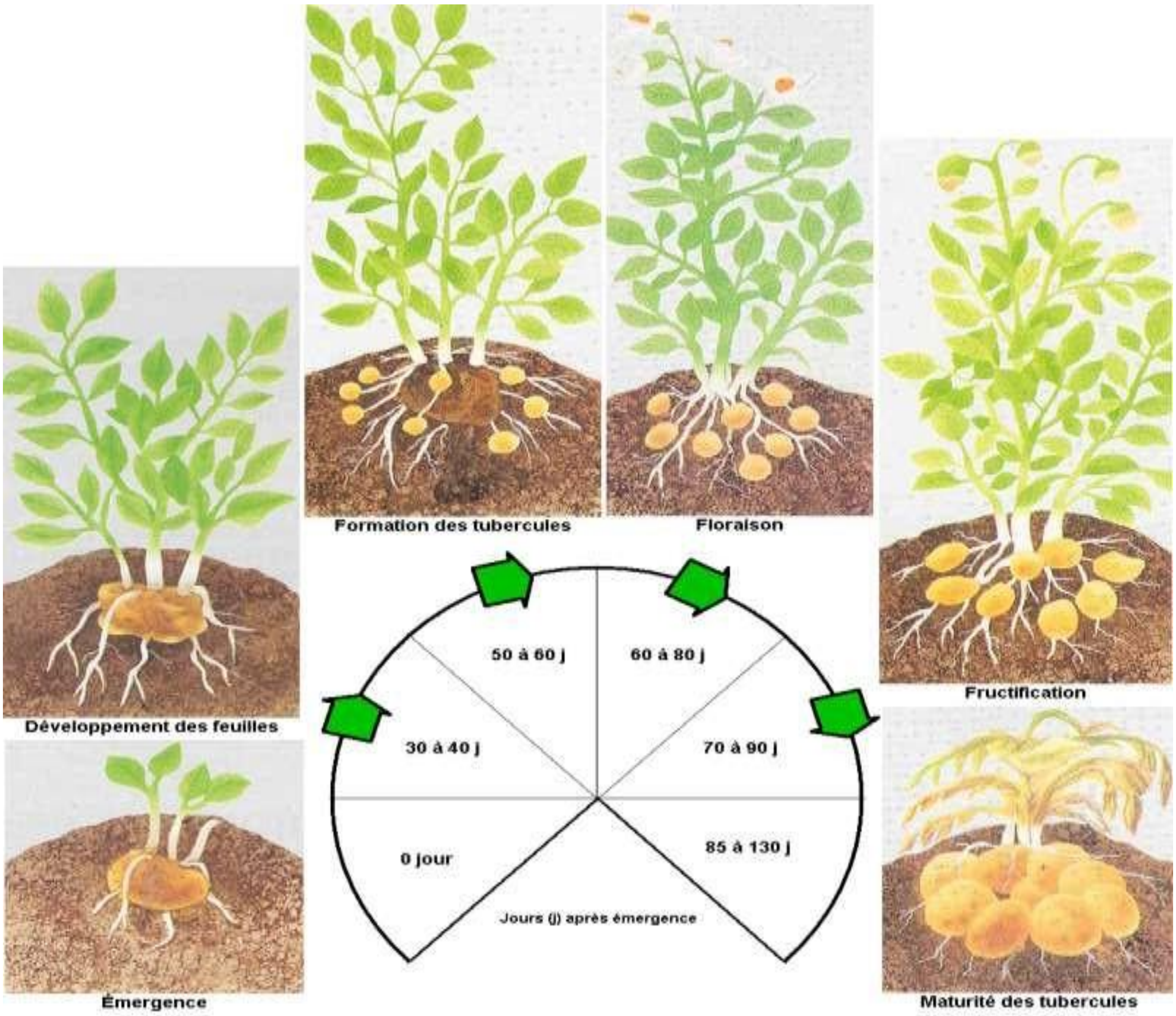

Figure 19: Potato development cycle.

7. Pedoclimatic Requirements

The potato has specific pedoclimatic requirements for proper development. The main requirements of the potato are:

- ***Climate***: The potato is a hardy plant that can grow in a wide range of climates, but prefers a temperate climate with an average temperature of 15 to 20°C. The minimum soil temperature at planting time: 8°C. The potato also requires a sufficient amount of water, about 500 to 800 mm per growing season.
- ***Soil***: The soil must be well-drained, deep, fertile, and rich in organic matter. The potato thrives in loamy or clay soils rich in nutrients and humus. The ideal soil pH for the potato is 5.2 to 6.5.
- ***Light***: The potato needs sufficient exposure to sunlight to produce a bountiful harvest. The

plants should receive about 6 to 8 hours of direct light per day.

- ***Altitude***: The potato can be grown up to altitudes of 2,500 meters, but altitudes of 1,500 to 2,000 meters are considered ideal for optimal growth.
- ***Diseases and Pests***: The potato is susceptible to several diseases and pests, including late blight, potato scab, tuber rot, and the potato fly. Prevention and control of these diseases and pests are essential to ensure a healthy harvest.
- These pedoclimatic requirements are general and may vary slightly depending on the potato variety and local conditions. It is therefore important to consult the specific recommendations for the potato variety and the growing region.

8. Cultivation techniques

8.1. Soil preparation

Soil preparation begins with plowing to break up clods and loosen the soil. Then, the soil is leveled and stones, weeds, and debris are removed.

Depending on the soil, an amendment may be added to improve its fertility. Deep soil tillage (plowing or chiseling) is done in autumn in heavy and medium-to-heavy soils, and in spring in silty to sandy soils. For light soils, tillage can be done in autumn or spring, with a preference for the latter. For seedbed preparation, the soil should be loosened to a depth of 10-15 cm to obtain a fine structure.

8.2. Variety selection

The choice of variety depends on the target market, climatic conditions, and soil characteristics. Early varieties can be planted earlier in the season and harvested earlier, while late varieties require a longer growing season.

8.3. Sprouting

Sprouting consists of exposing the tubers to high temperatures and high humidity for a few days before planting. This helps stimulate the germination of the tubers and accelerate plant growth.

8.4. Sprout removal

Sprout removal is the practice of removing weak or poorly formed sprouts from the tubers before planting. Sprouts are removed to ensure that the tubers have enough energy to produce roots and leaves.

8.5. Planting

Planting can be done manually or using a machine (Fig. 20). Furrows or holes are due to a depth of 10-15 cm and the tubers are planted with the sprout-end facing upwards. The plants are spaced according to the variety and the desired planting density. Potato planting takes place from early to late April, only in sufficiently warmed soils (maincrop potatoes) and in early March, under canvas or plastic (new potatoes).

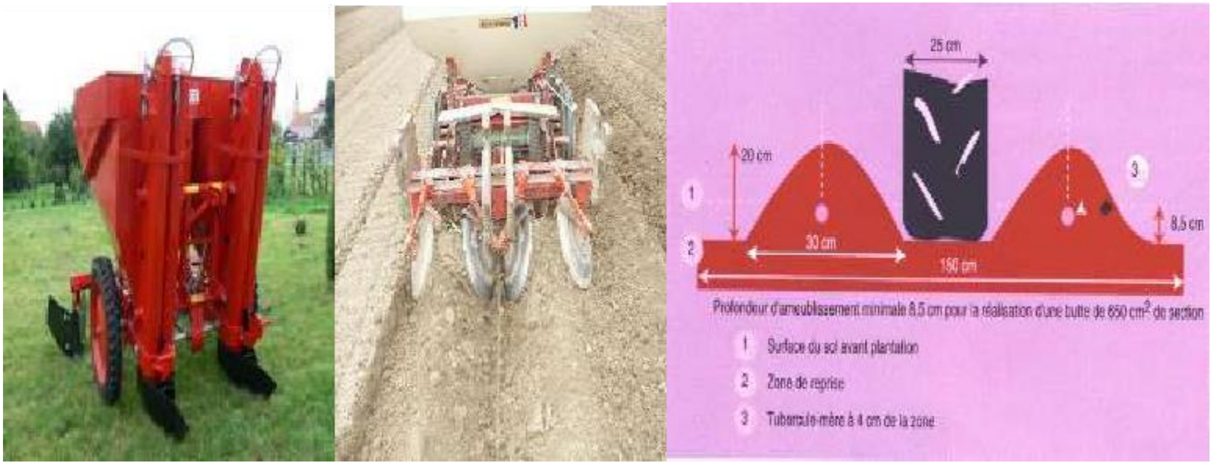

Figure 20: Potato planter.

The size of the seed potatoes can have an impact on the planting density, i.e., the number of potato plants planted per unit area. In general, large-sized seed potatoes produce larger and more productive plants, which allows for a lower planting density (Table 4).

Table 4: Average number of stems and tubers per plant according to seed size

Sizes	Number of stems per plant	Number of tubers per plant
28 – 35 mm	3 to 4	10 to 15
35 – 45 mm	5 to 6	15 to 20
45 – 55 mm	7 to 8	20 to 25

Small-sized seed potatoes produce smaller and earlier plants, which requires a higher planting density to obtain a satisfactory yield. Planting density can vary depending on the potato variety grown, growing conditions, desired plant size, and market requirements.

In general, it can be considered that for large-sized seed potatoes, the planting density can be around 30 to 40,000 plants per hectare, while for small-sized seed potatoes, it can be around 50 to 60,000 plants per hectare.

8.6. Fertilization

Fertilization can be carried out using organic or mineral fertilizers. The nutrient requirements of the potato vary depending on the variety, soil quality, and climatic conditions. Nitrogen is necessary for the growth of leaves and stems, while phosphorus and potassium are necessary for tuber formation.

Potatoes need balanced fertilization with nitrogen, phosphorus, and potassium to ensure optimal growth and production. In addition to these major elements, potato cultivation also requires other nutrients such as calcium, magnesium, sulfur, iron, manganese, zinc, boron, and copper.

In general, for an average production of 30 to 40 tons per hectare, the recommended quantities of fertilizers for potatoes are as follows:

- Nitrogen: 150 to 200 kg/ha
- Phosphorus: 100 to 150 kg/ha
- Potassium: 200 to 250 kg/ha

8.7. Hilling

Hilling consists of bringing soil up around the plants to protect the tubers from light and sun. This also improves the stability of the plants. Hilling is carried out two to three times during the growing season.

When the first leaves appear, the plants should be hilled. Soil should be gathered around the plants, forming cones about 20 centimeters high. Aligned in rows, the cones form a continuous line. It is in these mounds that the new tubers will develop (Fig. 21).

Figure 21 : Hilling potatoes.

8.8. Irrigation

Irrigation is essential for maintaining healthy growth of potato plants. Water should be provided regularly to avoid water stress. Water requirements vary depending on the soil and local climatic conditions.

Moderately dry soil during the beginning of vegetation promotes extensive deep rooting. At the beginning of stem elongation, the soil should be moist.

A dry period during tuber formation leads to a halt in vegetation and decreases in yield and quality.

Watering can limit frost damage down to -6°C for a short period. Start watering just before the freezing point.

Irrigation is necessary during long dry periods, and if needed, also after haulm killing to promote maturation (skin firmness).

8.9. Weeding

Weeding is an important practice for potato cultivation because it limits competition between plants and weeds for nutrients, water, and light. To effectively weed a potato crop, you must:

- ✓ *Weed regularly*: It is important to weed the potato crop regularly to prevent weeds from becoming too large and difficult to remove. Weeding should be done as soon as the weeds begin to grow.
- ✓ *Use appropriate tools*: There are several tools for weeding a potato crop, such as the hoe, the cultivator, or the weeding knife. It is important to choose the tool that is best suited to your land and growing conditions.

Weed by hand: If the potato crop is small, weeding by hand can be an effective option. This allows you to remove weeds precisely and avoid damaging the potato plants.

- ✓ *Use herbicides*: If manual weeding is not possible or proves ineffective, it is possible to use herbicides. However, it is important to carefully read the instructions and follow the manufacturer's recommendations to avoid harming the potato plants.
- ✓ *Avoid weeding too deeply*: It is important not to weed too deeply to avoid damaging the roots of the potato plants.
- ✓ *Dispose of weeding waste*: It is important to dispose of weeding waste to prevent it from becoming a source of disease or pests for the potato crop.

8.10. Pest and disease control

This is an important aspect of potato cultivation. For better management of diseases and pests, one of the following practices can be applied:

- ✓ *Variety selection*: It is important to choose varieties resistant to diseases and pests. Some potato varieties have a natural resistance to certain diseases such as late blight or potato cyst nematode.
- ✓ *Crop rotation*: It is important not to grow potatoes on the same soil for several years in a row to avoid the accumulation of diseases and pests.
- ✓ *Regular monitoring*: Regular monitoring of potato plants can help to quickly detect signs of diseases and pests. It is important to inspect potato plants for any signs of discoloration, wilting, or insect damage.
- ✓ *Use of biological products*: Biological products such as plant-based preparations can help prevent or treat diseases and pests without resorting to chemicals.
- ✓ *Use of chemical products*: In case of a major infestation, it may be necessary to use chemical products to control pests and diseases. It is important to follow the manufacturer's instructions and respect the recommended doses to avoid adverse effects on the plants and the environment.

8.11.Defoliation

Defoliation is an operation that involves cutting the foliage of potato plants to stimulate tuber maturation and facilitate their harvest.

The timing of defoliation depends on several factors such as the stage of crop development, weather conditions, and cultural practices. In general, defoliation is carried out about 2 to 3 weeks before harvest to allow the tubers to mature.

Defoliation can be done manually or mechanically. Manual defoliation involves cutting the foliage with a sickle or billhook. Mechanical defoliation can be carried out using a special machine called a "defoliator" which cuts the foliage at the base of the plants.

Ridging allows for an increase in the dry matter content of the tubers, which facilitates their preservation after harvest. It also improves the quality of the tubers by reducing the presence of diseases and promoting uniform maturation.

It is important not to ridge during wet weather to avoid the spread of diseases. It is also important not to cut the foliage too short to avoid injuring the tubers and promoting the entry of diseases.

8.12. Harvest

Harvesting should be done when the plants have reached maturity. This generally occurs about three months after planting. The tubers should be carefully extracted from the ground using a fork or a shovel. It is important to handle the tubers with care to avoid injury and damage.

- ***Harvest Time:*** Potato harvesting can be carried out when the plants have reached maturity, generally between 80 and 120 days after planting, depending on the variety grown.
- ***Harvesting Methods:*** Harvesting can be done manually or mechanically. The manual method involves digging up the plants using a spading fork or a shovel. The mechanical method can be carried out using a special machine called a "potato harvester".
- ***Precautions to be taken:*** It is important to handle the tubers carefully during harvesting to avoid damaging them. The tubers should be stored in a cool, dry place to prevent rotting. It is also important not to harvest potatoes in wet weather to avoid deterioration.
- ***Quality Control*** : It is important to sort the harvested tubers to remove diseased or damaged potatoes. Sorted potatoes should be stored separately to avoid contamination.

8.13. Storage

Potato tubers should be stored under appropriate conditions to prevent deterioration and rot. The tubers should be stored in a cool, dry place, at a temperature between 4 and 10 degrees Celsius, with a relative humidity of about 85%. The tubers should be stored in paper or cloth bags to allow for proper ventilation. It is important to regularly check the tubers for any signs of rot or damage and to remove them immediately.

Chapter 3:
Food Legumes (Pulses)

Chapter 3: Food Legumes (Pulses).

1. General Information

Food legumes belong to the Fabaceae family, which is a family of dicotyledonous plants. The family is also commonly called Legumes (Leguminosae) or Papilionaceae (Papilionaceae).

This family includes 18,000 species divided into three subfamilies (In classical classification, this group of plants would be the order Fabales with three families.). The three subfamilies are:

- Caesalpinioideae subfamily with a pseudo-papilionaceous flower;
- Mimosoideae subfamily with a regular flower;
- Faboideae or Papilionoideae subfamily with a typical butterfly-shaped flower.

The presence of nodules that fix atmospheric nitrogen is normally observed on the roots of Papilionoideae and Mimosoideae, while they are absent in most Caesalpinioideae. These nodules are the result of a symbiosis between nitrogen-fixing bacteria, rhizobia, and these different legume species.

A metabolic peculiarity of Fabaceae is the presence of an oxygen-binding heme protein, leghemoglobin (or LegHb), very similar to hemoglobin. This protein is found in the root nodules and allows oxygen to be fixed to form an aerobic environment favorable to the development of rhizobium.

2. Economic Importance

2.1. In the world

This is a family of great economic importance, being a source of plant protein for animal or human food that does not require nitrogen fertilizers. Thus, for many Fabaceae, their cultivation holds a special place in crop rotation due to their ability to fix atmospheric nitrogen thanks to rhizobium. It is also a source of fats and wood. There are also species that are of interest as ornamental plants.

The Fabaceae family includes cultivated plants such as: beans, peas, lentils, peanuts, soybeans, licorice, alfalfa, clover, lupin, "wisteria", rosewood, etc.

According to data from the FAO (Food and Agriculture Organization of the United Nations), global legume production in 2020 amounted to approximately 77 million tons. According to FAO data, global food legume production has seen a slight increase over the past ten years. In 2010, global production was around 68 million tons, while in 2020, it was around 77 million tons (Fig. 22). However, it should be noted that production can vary considerably from year to year depending on factors such as weather conditions, diseases, and changes in market demand.

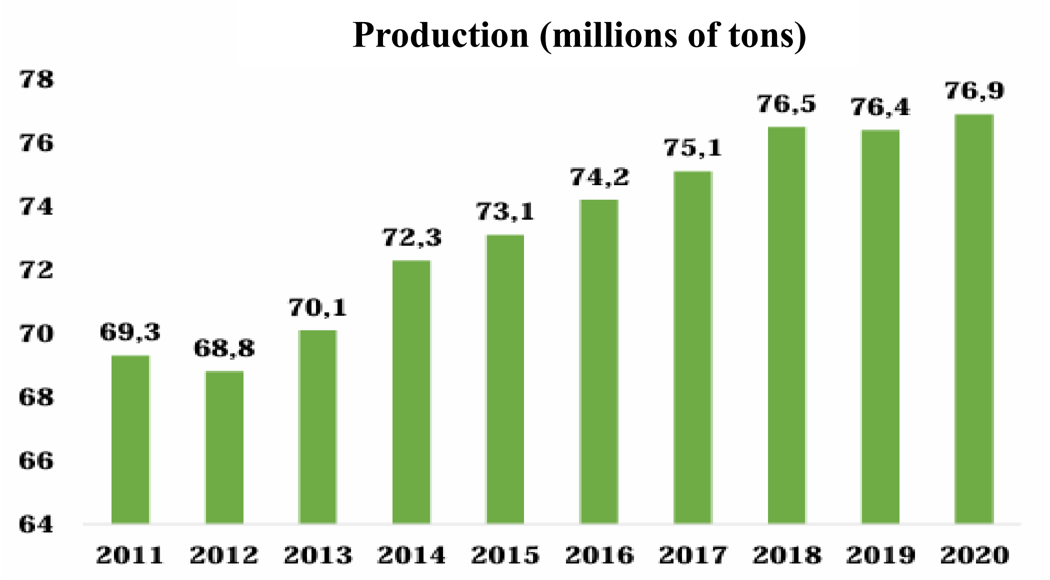

Figure 22: Evolution of food legume production from 2011 to 2020 (**FAO, 2021**).

India is the world's leading producer of food legumes, followed by Canada, Burma, Australia, and the United States (Fig. 23). Legumes are grown in many countries, but India and other Asian countries are the largest producers.

The most produced food legumes in the world are: beans, peas, lentils, chickpeas, soybeans, peanuts, and broad beans (Fig. 24). These legumes are cultivated for their nutritional value as a source of plant protein, dietary fiber, vitamins, and minerals. They are also used for animal feed, biofuel production, and other industrial uses. Production quantities can vary from year to year and from country to country.

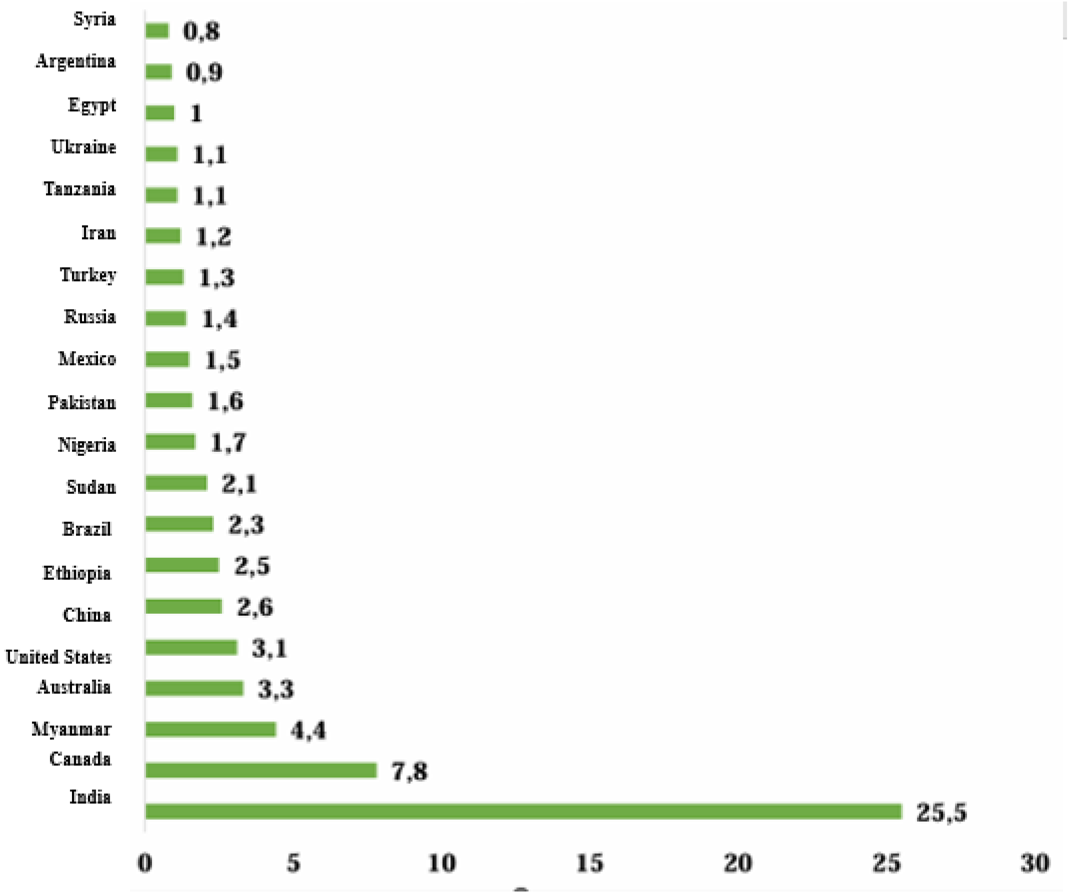

Figure 23: Food legume production by country (**FAO, 2021**).

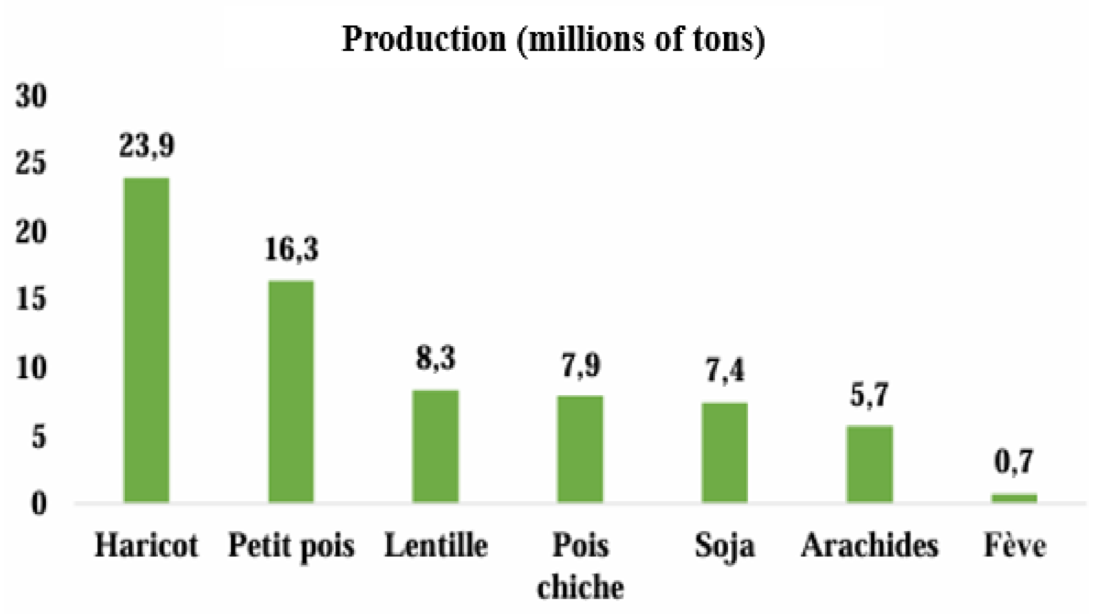

Figure 24: The most produced food legumes in the world.

2.2. In Algeria

Food legume production in Algeria is relatively significant, as legumes are an important component of the country's traditional diet. According to the latest FAO data for 2020, total food legume production in Algeria was approximately 780,000 tons, with beans, chickpeas, and lentils being the most important crops. Bean production was approximately 370,000 tons, followed by chickpeas with approximately 250,000 tons and lentils with approximately 140,000 tons. Other legumes such as peas and broad beans are also produced in Algeria but on a smaller scale.

There has been some fluctuation in food legume production in Algeria in recent years, with an increase in production between 2011 and 2013, followed by a slight decrease until 2015, and a slight increase until 2018. Since 2019, production has slightly increased to reach 780,000 tons in 2020 (Fig. 25).

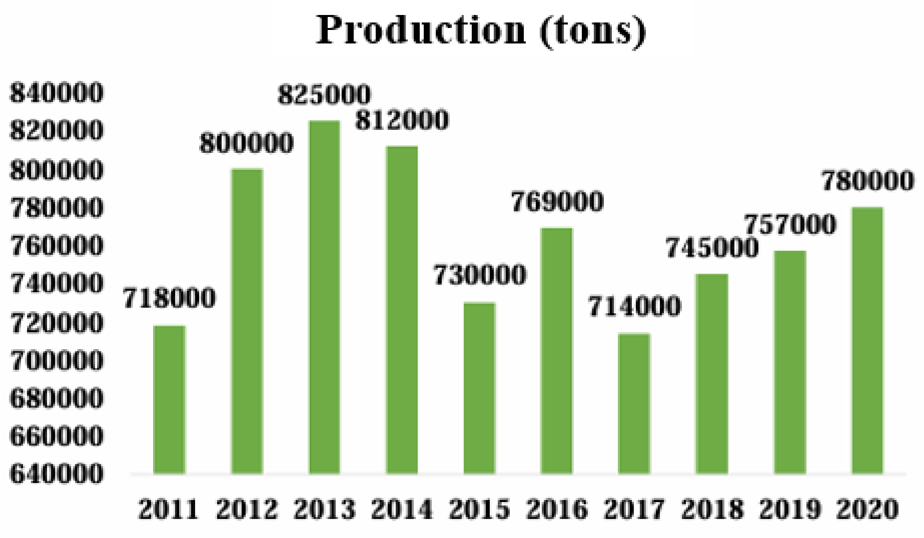

Figure 25: Evolution of food legume production in Algeria from 2011 to 2020 (**FAO, 2021**).

Food legume production areas in Algeria are spread throughout the country. However, food legume cultivation is concentrated in the agricultural areas of the northern, eastern, and western regions of the country, due to the favorable climatic conditions for legume cultivation. The most productive areas for food legumes are Blida, Chlef, Tizi Ouzou, Sétif, Béjaia, Médéa, Tlemcen, Batna, and Tipaza.

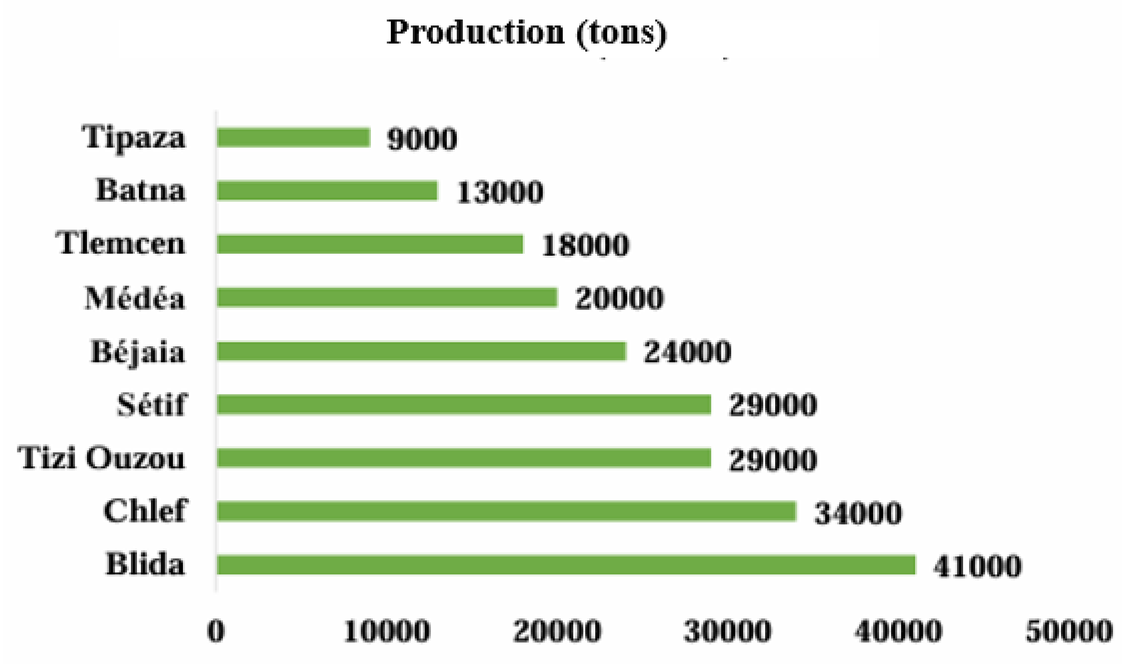

Figure 26: The most productive areas for food legumes in Algeria (**FAO, 2021**).

3. Nutritional Value

Food legumes, such as chickpeas, lentils, beans, broad beans, and peas, are an excellent source of essential nutrients for our body. They are rich in protein, fiber, vitamins, and minerals, while being low in fat and calories. The essential nutrients that can be found in legumes are:

- ***Protein:*** Legumes are an excellent source of plant-based protein. They contain on average 20 to 25% protein, making them an ideal food for vegetarians and vegans looking to increase their protein intake.
- ***Fiber:*** Legumes are rich in dietary fiber, which is essential for maintaining healthy and regular digestion. Fiber can also help lower blood cholesterol, control blood sugar levels, and promote weight loss.
- ***Vitamins***: Legumes contain a variety of vitamins, including vitamin A, vitamin B6, vitamin C, vitamin E, and vitamin K. Vitamin B9, also called folic acid, is particularly important for pregnant women or those considering pregnancy, as it is essential for fetal growth and development.
- ***Minerals***: Legumes are rich in minerals such as iron, calcium, magnesium, potassium, and zinc. Iron is important for red blood cell formation, while calcium and magnesium are essential for bone health. Potassium is important for regulating blood pressure, while zinc is important for immune function and wound healing.

In addition to their high nutrient content, legumes are also very versatile and can be used in a variety of dishes, such as soups, salads, stews, curries, and hummus.

4. Botanical Description

4.1. Roots

Food legumes have roots that vary in shape and depth depending on the species and the growing environment. The general characteristics of food legume roots are:

- ✓ ***Taproots***: Most food legumes have taproots that can reach several meters deep into the soil. Taproots are important for the absorption of water and nutrients, and can also help maintain the stability of the plant (Fig. 27A, Fig. 27B).
- ✓ ***Root Nodules***: Some legumes, such as beans, peas, lentils, and broad beans, have the ability to form root nodules that house symbiotic bacteria capable of fixing atmospheric nitrogen. Nodules are bulb-shaped structures that form on the roots and are essential for the growth and development of legumes (Fig. 27C).
- ✓ ***Adventitious Roots***: Some legumes can also produce adventitious roots, which are roots that form from the stem rather than the main root (Fig. 27D). Adventitious roots can help improve nutrient and water absorption, especially in poor soil conditions or drought.
- ✓ ***Branched Roots***: Legumes can also have branched lateral roots that extend horizontally in the soil. Branched roots can help increase the surface area for nutrient and water absorption, and can also contribute to the stability of the plant.

Figure 27: Roots of some food legumes: Taproots (A and B), nodules (C) and adventitious roots (D).

In general, the roots of food legumes are important for the absorption of nutrients and water, as well as for the fixation of atmospheric nitrogen in the soil. The different characteristics of the roots can also contribute to the resilience of the plant in the face of unfavorable environmental conditions.

4.2. Stems

The stems of food legumes have several common characteristics, although they can vary depending on the species. The characteristics of food legume stems are:

- ***Erect stems***: The stems of food legumes are generally erect and straight, and can reach a height ranging from a few centimeters to several meters, depending on the species and growing conditions.
- ***Hollow stems***: The stems of food legumes are often hollow, which allows them to transport water and nutrients from the root to the upper parts of the plant.
- ***Woody stems***: Some legumes, such as bean trees and acacias, have woody stems that can reach a significant size and thickness. Woody stems are important for plant stability, as well as for storing water and nutrients.
- ***Creeping stems***: Some legumes, such as runner beans and climbing peas, have creeping stems that allow them to spread along the ground or climb vertical structures. Creeping stems can contribute to soil stabilization, as well as protection against erosion.

The differences that exist between the stems of the most consumed food legumes in Algeria (chickpea, pea, bean, lentil and broad bean) are:

- ***Chickpea***: Chickpea stems are erect and can reach up to 50-60 cm in height. They are relatively thin and flexible, with medium-sized leaves. The stems may tend to wrap around supports (Fig. 28A).
- ***Pea***: Pea stems are also erect and climbing. They can reach up to 2 meters in height. They are quite thin and need support to climb (Fig. 28B).
- ***Bean***: Bean stems can vary in height depending on the species, but they are generally erect and can reach several meters in height. They are thicker than those of other legumes, with larger leaves. The stems are often woody and can withstand strong winds (Fig. 28C).
- **Lentil**: Lentil stems are also erect and can reach up to 40 cm in height. They are relatively thin and flexible, with small leaves. The stems may tend to spread along the ground rather than stand upright (Fig. 28D).
- **Broad bean**: Broad bean stems are erect and can reach up to 1.5 meters in height. They are

quite thick and woody, with large leaves (Fig. 28E). The stems are often resistant and can withstand harsh environmental conditions.

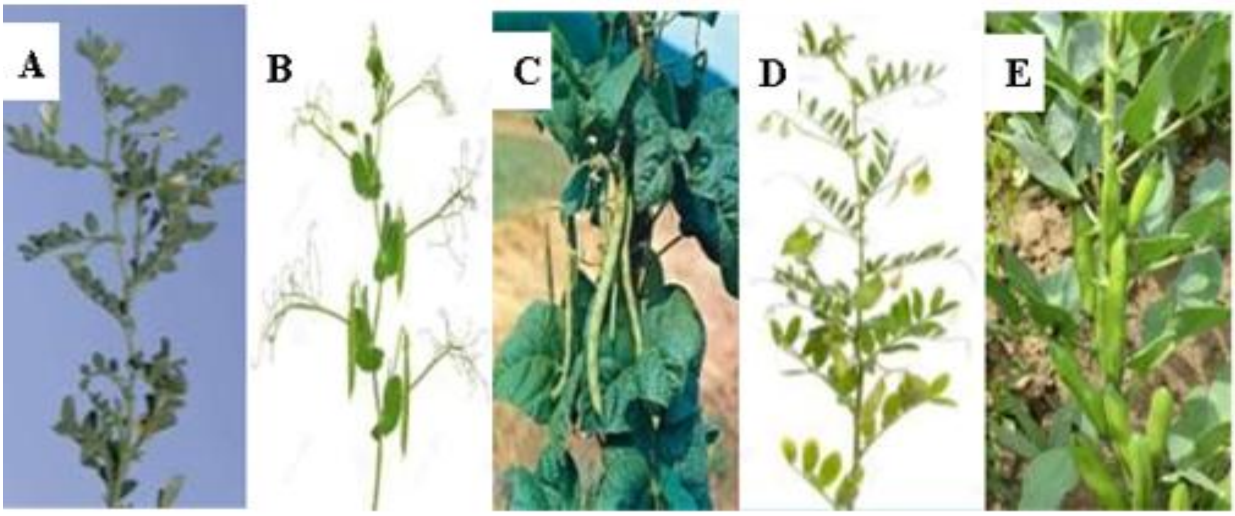

Figure 28: Stems of some food legumes: Chickpea (A), Pea (B), Bean (C), Lentil (D) and broad bean (E).

4.3. Leaves

The leaves of food legumes generally have a complex morphology, as they are composed of several leaflets. Leaflets are small leaves that are located on a central stem called the rachis. The leaflets are arranged symmetrically on either side of the rachis, and can vary in size and shape depending on the legume species. The leaflets are oval, lanceolate or rounded, with a pointed or rounded tip, and can vary in size and color depending on the species.

In general, the leaves of food legumes have an oval or heart shape, and can measure from a few centimeters to several tens of centimeters in length. The leaves are often alternate, meaning they develop on opposite sides of the stem, but there may be species with opposite or whorled leaves.

The leaves can also have a hairy texture, which is due to the presence of small hairs on the leaf surface. These hairs can protect the plant against insects and diseases, as well as regulate water evaporation.

In addition, the leaves of food legumes can vary in color depending on the species and variety. They can be light green, dark green, silver, or even purple.

The veins of the leaves are often well marked, with main and secondary veins that bring water and nutrients to the different parts of the leaf.

The differences that exist between the leaves of the most consumed food legumes in Algeria (chickpea, pea, bean, lentil and broad bean) are:

- ***Chickpea***: the leaves are composed of several pairs of oval or lanceolate leaflets, which are rather small and light to medium green. They are often arranged alternately along the stem (Fig. 29A).
- ***Pea***: the leaves are composed of several pairs of oval or rounded leaflets, which are larger than those of the chickpea and have a smooth, velvety texture. They are also arranged alternately along the stem (Fig. 29B).
- ***Bean***: the leaves are composed of three oval leaflets, light to medium green in color, with a slightly hairy texture. The leaves are often arranged alternately along the stem (Fig. 29C).
- ***Lentil***: the leaves are composed of several pairs of oblongs, oval or lanceolate leaflets, which are light to medium green. They are often arranged alternately along the stem (Fig. 29D).
- ***Broad bean***: the leaves are composed of several pairs of oval or lanceolate leaflets, which are larger than those of the chickpea and a shiny dark green. They are often arranged alternately along the stem (Fig. 29E).

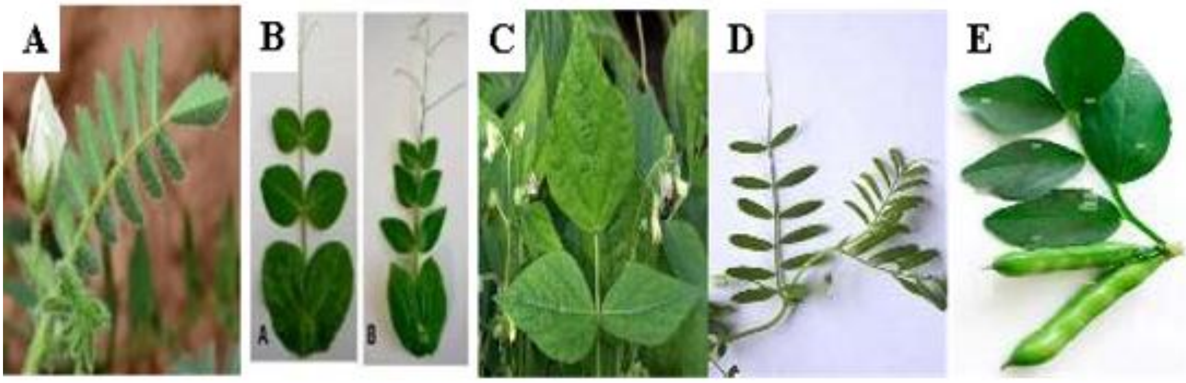

Figure 29: Leaves of some food legumes: Chickpea (A), Pea (B), Bean (C), Lentil (D) and broad bean (E).

4.4. Flowers

The flowers of food legumes are often very recognizable thanks to their unique structure. The characteristics of the flowers of food legumes in general are:

- ***Bilateral symmetry***: The flowers of food legumes are characterized by bilateral symmetry, which means they can be divided into two symmetrical parts, left and right.

- ***Five petals***: The flowers generally have five petals arranged in a butterfly shape, one of which is larger than the others and called the keel. The other petals are called the wings.
- ***Ten stamens***: The flowers also have ten stamens, which are the male organs of the flower. The stamens are arranged in two groups: nine stamens are grouped around the ovary and the tenth stamen is isolated.
- ***Superior ovary***: The ovary, which is the female organ of the flower, is located at the top of the flower's receptacle. The flowers of food legumes have a superior ovary, which means that the petals, stamens, and other parts of the flower are attached to the base of the ovary.

The flowers of chickpea, pea, bean, lentil and broad bean have some similarities, but there are also notable differences.

- ✓ ***Chickpea flowers***: Chickpea flowers are white or pale pink and have a butterfly shape. They are larger than pea and lentil flowers, and are
- ✓ often grouped in clusters. Chickpea flowers are self-fertile and can therefore self-pollinate (Fig. 30A).
- ✓ ***Pea flowers***: Pea flowers are also butterfly-shaped, but are smaller than chickpea flowers. They are generally white, pink or purple and are also grouped in clusters. Pea flowers require cross-pollination to produce pods (Fig. 30B).
- ✓ ***Bean flowers***: Bean flowers are white or purple and have a bell shape. They are smaller than chickpea and pea flowers, and are generally grouped in clusters. Bean flowers also require cross-pollination to produce beans (Fig. 30C).
- ✓ ***Lentil flowers***: Lentil flowers are very small and have a white, pink or purple color. They are also butterfly-shaped, but are smaller than chickpea and pea flowers. Lentil flowers are self-fertile and can therefore self-pollinate (Fig. 30D).
- ✓ ***Broad bean flowers***: Broad bean flowers are white or pale pink and have a butterfly shape. They are larger than lentil flowers, but smaller than chickpea and pea flowers. Broad bean flowers also require cross-pollination to produce pods (Fig. 30E).

In summary, chickpea and broad bean flowers are larger and have a butterfly shape, while pea, bean and lentil flowers are smaller and have a bell or butterfly shape. Chickpea and lentil flowers are self-fertile, while pea, bean and broad bean flowers require cross-pollination.

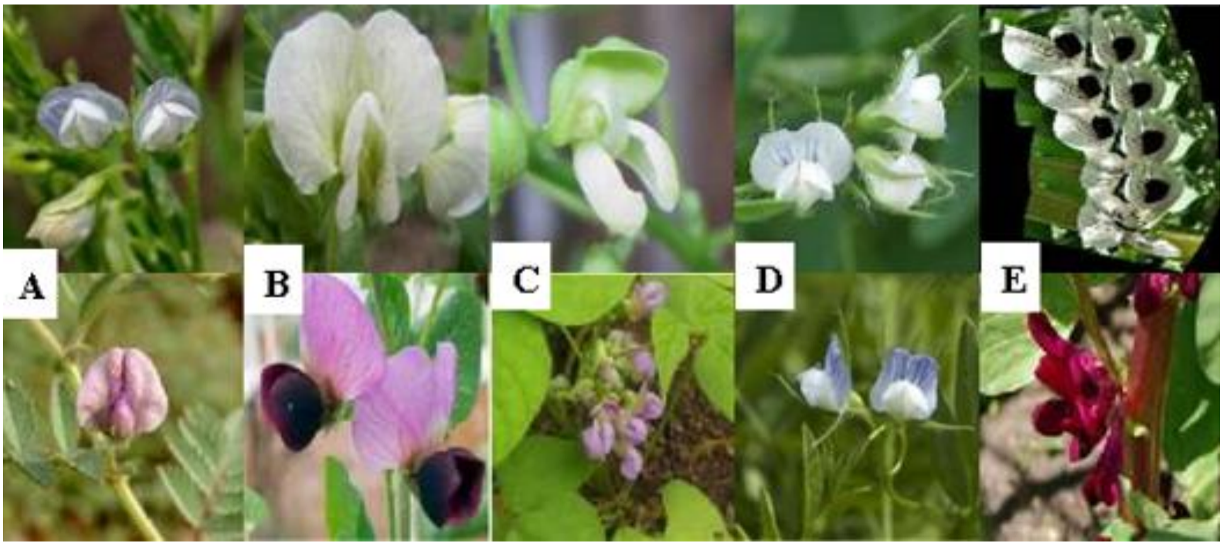

Figure 30: Flowers of some food legumes: Chickpea (A), Pea (B), Bean (C), Lentil (D) and Broad bean (E).

4.5. Fruits (pods)

Food legumes produce fruits called pods that contain the seeds we eat. Although the shape and size of the pods vary depending on the legume species, they have similar morphological characteristics. The morphology of the fruits (pods) of food legumes can be described as follows:

- ✓ Legume pods are dehiscent dry fruits, meaning they open at maturity to release the seeds inside. The pods are green for some species.
- ✓ Pods are formed from the ovaries of flowers, and can be simple or compound.
- ✓ The shape of the pods varies depending on the legume species, but they are generally elongated, cylindrical, or flattened.
- ✓ Pods are often divided into two halves, separated by a seam called a suture.
- ✓ Inside the pod, the seeds are arranged in rows, attached to the suture.
- ✓ Pods are usually harvested before they are fully ripe and dried, as the seeds are more tender and tastier at this stage. The pods can be eaten in some cases, but most of the time, only the seeds are used for food.

The pods of food legumes vary in shape, size, and color depending on the species. The differences between the pods of the most common legumes are:

- ➢ ***Chickpeas:*** Chickpea pods are elongated, measuring about 2 to 3 cm in length. They generally contain two to three spherical beige seeds, which are edible (Fig. 30A).

- ***Peas:*** Pea pods are cylindrical, green in color, and can measure from 5 to 10 cm in length. They contain several round, sweet seeds (Fig. 30B).
- ***Beans:*** Bean pods are often flattened and can measure up to 20 cm in length. They contain several oblong seeds, often round or oval in shape (Fig. 30C).
- ***Lentils:*** Lentil pods are flattened and can measure from 1 to 2 cm in length. They contain two to three small seeds, often round or oval in shape (Fig. 30E).
- ***Broad beans:*** Broad bean pods are often flattened and measure from 5 to 15 cm in length. They contain several oval seeds, often beige or green in color (Fig. 30E).

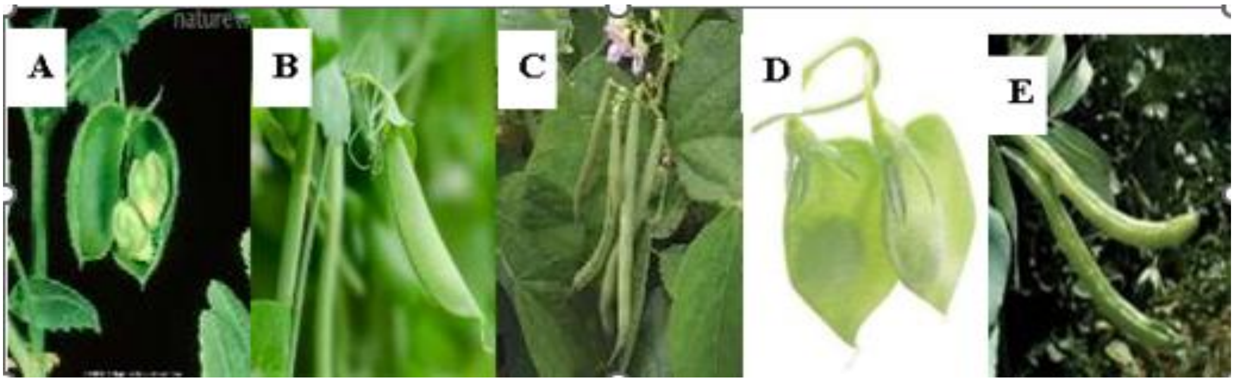

Figure 31: Pods of some food legumes: Chickpea (A), Pea (B), Bean (C), Lentil (D) and Broad bean (E).

4.6. Seeds

The seeds of food legumes have a similar morphology in general. The main characteristics of legume seeds are:

- ***Shape:*** Legume seeds generally have a spherical, oval, or oblong shape.
- ***Size:*** The size of the seeds varies depending on the species, but in general, they range in size from a few millimeters to more than one centimeter.
- ***Texture:*** Legume seeds are often smooth and hard, with a surface that can be slightly wrinkled or textured.
- ***Color***: The color of legume seeds also varies depending on the species. Some seeds can be beige, yellow, green, brown or black, and some may have spots or patterns.
- ***Germination***: Legume seeds have a high germination capacity, which makes them popular for cultivation as food crops.

The seeds of food legumes have distinct differences in terms of size, color, shape, and taste. The differences between the seeds of the most common food legumes are:

- ***Chickpea***: Chickpea seeds are relatively large, round and slightly irregular in shape (Fig 32A). They are light beige in color and have a nutty taste.
- ***Pea***: Pea seeds are relatively small and round and smooth in shape (Fig 32B). They are green in color and have a sweet and delicate taste.
- ***Bean***: Bean seeds are generally larger than pea seeds and have an oblong and slightly curved shape (Fig. 32C). They are white, beige, red or black in color and have an earthy and slightly sweet taste.
- ***Lentil***: Lentil seeds are relatively small and round, with a smooth surface

(Fig. 32D). They are olive green, brown or orange in color and have a mild and slightly nutty taste.

- ***Broad bean***: Broad bean seeds are relatively large and oval in shape (Fig. 32E). They are green or beige in color and have a mild and slightly bitter taste.

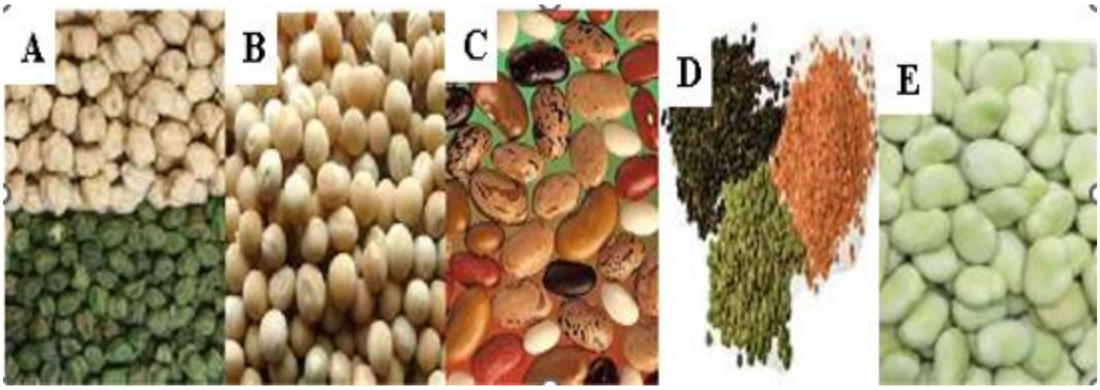

Figure 32: Seeds of some food legumes: Chickpea (A), Pea (B), Bean (C), Lentil (D) and Broad bean (E).

5. Development Cycle

The development cycle of food legumes depends on the type of legume, but in general, it consists of the following stages (Fig. 33):

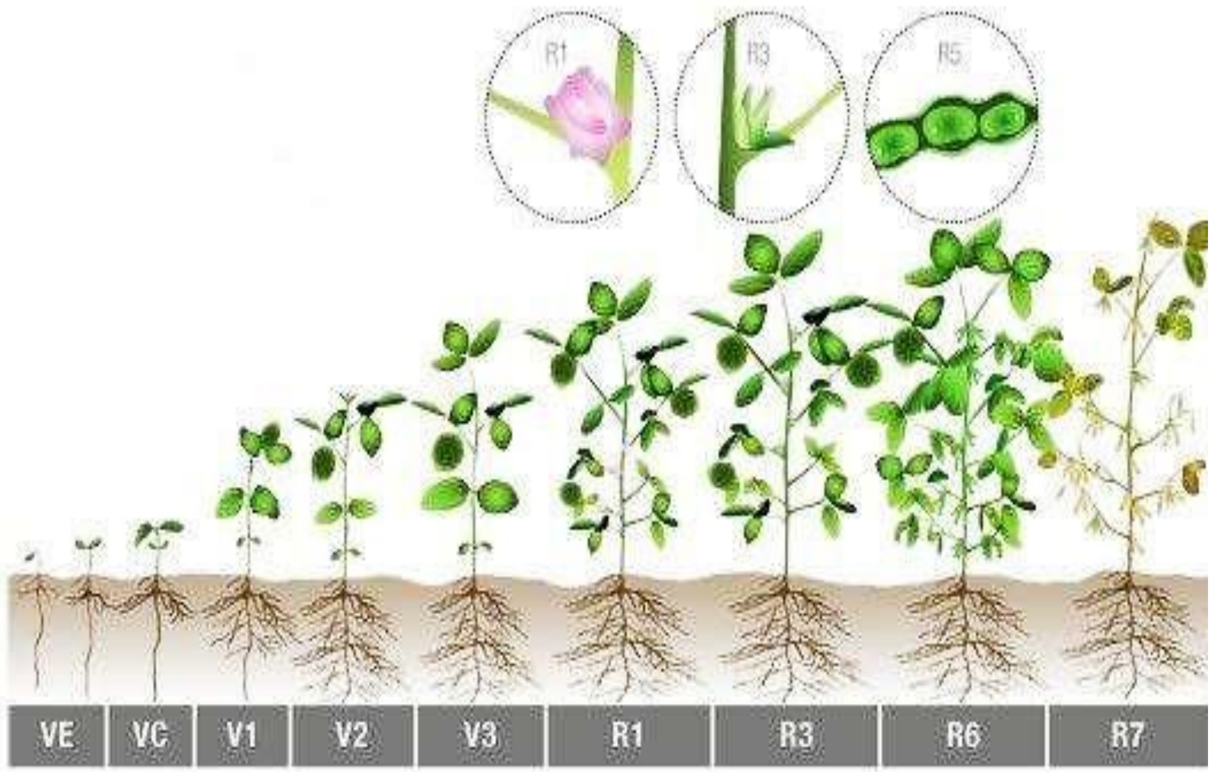

Figure 33: Life cycle of a food legume.

(VE: Emergence, VC: cotyledon leaf development, V1-V3: Vegetative growth, R1: Flowering, R2: Fertilization (fruit set), R6 Pod formation and seed filling, R7: Maturity).

5.1. Vegetative cycle

5.1.1. Germination

Germination is the initial stage of legume growth. It is a complex biological phenomenon that involves a series of important steps:

- ***Imbibition***: Germination begins with the absorption of water by the seed. This causes the protective membrane of the seed to break, allowing water to enter the seed.
- ***Enzymatic activation***: The absorption of water triggers the activation of enzymes in the seed. The enzymes begin to break down the nutrient reserves stored in the seed, to provide energy to the growing seedling.
- ***Radicle Elongation***: The radicle, or the plant's first root, begins to elongate and pierce the seed coat. This allows the plant to firmly anchor its roots in the soil and begin absorbing the nutrients necessary for its growth.
- ***Stem Emergence***: After the radicle has emerged, the stem of the young plant begins to

develop and emerge from the seed. The stem is responsible for the plant's growth towards sunlight and for photosynthesis.

❖ ***Leaf Development***: The first leaves of the young plant begin to develop, allowing the plant to start producing its own food through photosynthesis, this is ***emergence***.

In leguminous seed plants, the germination process is generally rapid and takes between 3 and 7 days. Legumes are particularly well-suited to germination because they contain significant nutrient reserves in their seeds, which allows the young plant to develop quickly and become self-sufficient in terms of nutrition.

5.1.2. Emergence

The duration of emergence varies depending on the legume species and environmental conditions, but it is generally a few days to a week. Factors that influence legume emergence include temperature, soil moisture, sowing depth, seed quality, and the presence of diseases or pests.

During emergence, it is important to ensure that the young legume seedlings are not smothered by weeds, which can compete with the developing plant for water, nutrients, and light. Managing sowing density is also important to avoid competition between plants and promote the healthy growth of each seedling.

Good emergence is essential to ensure healthy and vigorous growth of legumes throughout their life cycle. Legumes are plants that have great agronomic, nutritional, and environmental potential, and successful emergence is a crucial step in maximizing their contribution to human and animal food, as well as to the sustainability of agricultural systems.

5.1.3. Vegetative Growth

The vegetative growth of food legumes is an important stage in their development, which occurs after emergence and before flowering. It includes the growth of leaves, stems, and roots, as well as the accumulation of biomass and nutrients in the plant.

First, the leaves and stems of legumes develop from the seed during germination. The first leaves, called cotyledons, provide a source of nutrients for the young plant until it is able to produce its own food through photosynthesis.

Then, the growth of leaves and stems is stimulated by growth hormones such as auxin, cytokinin, and gibberellic acid. These hormones promote cell division and the growth of existing cells, allowing the plant to develop.

Legume buds are responsible for the growth of stems, branches, and leaves. Bud growth is regulated by growth hormones. Auxin is produced in the leaves and is transported to the buds, which promotes their growth and development. Cytokinin is produced in the roots and is transported upwards in the plant, which promotes the growth of lateral buds.

Internode growth allows the plant to lengthen. It is influenced by the same growth hormones as bud growth, as well as by environmental conditions such as light, temperature, and humidity.

Branching occurs when new lateral buds form on the main stems. Branching can be stimulated by growth hormones such as cytokinin, as well as by pruning and trimming the main stems. In legume crops, branching can be desirable as it can increase leaf area and improve seed production.

The process of photosynthesis also plays a key role in the growth of leaves and stems of legumes. Leaves absorb sunlight and use this energy to produce sugars and other organic compounds. These organic compounds are then transported throughout the plant to support the growth and development of leaves and stems.

In addition, the environment also plays an important role in the growth of leaves and stems of food legumes. The availability of light, water, and nutrients can affect the growth and development of the plant. For example, a lack of water can lead to stunted growth of leaves and stems, while an excess of nitrogen can lead to excessive leaf growth at the expense of stem growth.

Finally, the genetics of the plant itself can also influence the growth of leaves and stems. Some legume varieties have faster growth or a better ability to produce leaves and stems than other varieties.

5.2. Reproductive Cycle

5.2.1. Flowering

Flowering is an important process in the life cycle of food legumes because it is at this stage that the flowers turn into fruits and seeds.

Flowering in legumes is generally triggered by environmental cues such as photoperiod (the length of the day), temperature, and humidity. Legumes have indeterminate flowering, which means that flowers continue to form and open on the stems for an extended period.

Fertilization in legumes begins with pollination, which is the transfer of pollen from the stamens to the stigma of the pistil of the same flower or another flower on the same plant. Pollinators such as bees, butterflies, and beetles play an important role in the pollination of legume flowers.

Once the pollen reaches the stigma, it germinates and produces a pollen tube that grows towards the ovary. The pollen tube contains the male gametes which fuse with the female gametes of the ovule, producing a single cell called a zygote. The zygote then divides multiple times to form an embryo that will become the seed.

In some legume species, such as soybeans, cross-fertilization is favored, which means that the plants are pollinated by external pollinators such as bees. Other species, such as beans, are self-fertile and can self-pollinate.

Once the flower is pollinated, the pistil develops into a fruit or pod that contains the seeds. Pods can be of different shapes and sizes, depending on the legume species, and can contain one or more seeds.

5.2.2. Pod Formation

Pod formation in food legumes is a process that occurs after fertilization and involves the transformation of the flower's ovary into a pod that will contain the developing seeds.

Once fertilization has taken place, the flower's pistil begins to develop to form the pod. The pod is generally a long, narrow structure that develops from the base of the flower and gradually extends.

As the pod develops, it fills with liquid and nutrients, which nourish the developing seeds inside. The pod is also covered with an outer layer called the cuticle, which protects it from damage and dehydration.

During pod formation, the plant also continues to grow and produce new leaves and stems. In some legume species, such as peas, the pods are harvested before they are fully developed, while the seeds are still small and tender. In other species, such as beans, the pods are harvested when the seeds are fully developed and mature.

5.2.3. Seed Filling

Seed filling in food legumes is a crucial process that follows fertilization and pod formation. During this stage, the developing seeds accumulate nutrient reserves, including proteins, carbohydrates, and lipids, which are stored in the cotyledons (the embryonic leaves of the seed) to support the growth of the new plant once the seed has germinated.

Seed filling begins shortly after fertilization, when the seed cells begin to divide and differentiate to form the different parts of the mature seed.

As the seeds develop, they accumulate reserves of nutrients that are stored in the cotyledons. In legumes, the cotyledons are often fleshy and rich in protein, making them an important source of nutrients for humans and animals.

The seed filling process continues until the seeds reach their maximum size and maturity. At this point, the seeds are harvested and can be used for human or animal consumption, or for the production of seeds for growing new plants.

5.3. Maturity

Maturity in food legumes is reached when the seeds have completed their filling and have reached their maximum size and weight. At this stage, the plant begins to dry and lose its characteristic green color, the leaves turn yellow, and the pod dries out.

Maturity is an important time in the life cycle of legumes, as it is at this point that the seeds are ready for harvest and consumption. Harvesting legumes must be done at the right time, because if it is done too early, the seeds may not be fully developed and may not have reached their maximum nutrient content. If it is done too late, the seeds may detach from the pods and fall to the ground, making harvesting more difficult.

The maturity of legumes can be determined by monitoring the color and texture of the pod, as well as the color of the seeds. When the pods begin to yellow and dry out, and the seeds have reached their maximum size and weight, the legumes are ready to be harvested.

It is important to note that maturity can vary depending on the type of legume and growing conditions. For example, some bean varieties reach maturity faster than others, and legumes grown in hot, dry climates can mature faster than those grown in cooler, wetter climates.

6. Ecological Requirements

Food legumes have specific ecological requirements for their growth and development. These requirements are:

6.1. Temperature

Legumes need moderate temperatures for their growth and development. Optimal temperatures vary depending on the type of legume, but generally, they are between 18°C and 27°C.

6.2. Light

Legumes need plenty of light for their growth. They prefer sunny locations, but can also grow in partial shade.

6.3. Water

Legumes need a regular supply of water for their growth and development. Water requirements vary depending on the type of legume, climate, and season. Some legumes can tolerate periods of drought, while others need a constant supply of water.

6.4. Soil

Legumes prefer well-drained and fertile soils. They can tolerate a wide range of soil pH, but prefer a neutral to slightly acidic pH. Legumes can also fix atmospheric nitrogen in the soil through symbiosis with nitrogen-fixing bacteria, which can contribute to soil fertility.

6.5. Nutrients

Legumes need essential nutrients such as phosphorus and potassium for their growth and development. They may also need other elements such as calcium, magnesium, and sulfur. They have the ability to fix atmospheric nitrogen, therefore their need for nitrogen fertilization is low. However, they need a small amount of nitrogen to start before the formation of symbiosis with rhizobacteria.

It is important to note that the ecological requirements of legumes can vary depending on the type of legume and growing conditions. For example, some legumes may be more drought tolerant than others, and some can grow in nutrient-poor soils. Ecological requirements can also vary depending on the geographical region and local climatic conditions.

7. Technical Itinerary

The technical itinerary for a food legume crop can vary depending on the legume variety, climate, agricultural practices, and soil conditions. The main steps involved in growing food legumes are:

7.1. Soil Preparation

Soil preparation for a food legume crop depends on several factors, including soil type, climatic conditions, legume variety, and local farming practices. Here are some basic steps to prepare the soil for a food legume crop:

 Soil Analysis: It is important to know the soil properties before starting any cultivation. A soil analysis will determine the soil pH, nutrient levels, soil texture, and other important parameters for plant growth. Based on the results of the analysis, it may be necessary to adjust the soil pH and add amendments to provide additional nutrients.
 Weeding: It is important to weed the soil before planting to eliminate weeds that could compete with the food legume crop for water, nutrients, and light.
 Plowing: Plowing the soil allows you to turn over the topsoil to loosen and aerate the soil, which facilitates plant rooting. Plowing can also help incorporate amendments such as organic fertilizers or organic matter.
 Leveling: Leveling the soil creates a uniform surface to facilitate planting and irrigation. It is important to ensure that the soil surface is well leveled to prevent water accumulation in the lower areas of the field.
 Deep Tilling: If the soil is compacted or poorly drained, it may be necessary to till the soil deeply to improve the soil structure and allow for better water and air circulation.

7.2. Fertilization

The fertilization of food legumes depends on the nutrient needs of each species, the type of soil, and the cultivation practices used. Legumes are able to fix atmospheric nitrogen thanks to their symbiosis with bacteria of the genus Rhizobium, which allows them to have a significant nitrogen supply. However, for optimal growth, legumes need other nutrients such as phosphorus, potassium and trace elements.

Before planting, a soil test can be carried out to determine the levels of available nutrients and adjust the amounts of fertilizer needed. Organic fertilization can be used to provide additional nutrients and improve soil structure. Organic fertilizers such as compost or manure can be incorporated into the soil before planting or applied to the surface.

For nitrogen, it is recommended to apply a nitrogen-containing fertilizer before planting, but applying nitrogen fertilizer during cultivation can inhibit the fixation of atmospheric nitrogen by Rhizobium bacteria. It is therefore preferable to use fertilizers containing nitrogen in a slow-release form, such as organic fertilizers.

For phosphorus and potassium, the doses can vary depending on the needs of the different food legume species. It is also possible to apply foliar fertilizers to provide nutrients directly to the leaves and stems of the plants.

Finally, it is important to note that food legumes can be sensitive to excess nitrogen and soil pH that is too acidic. It is therefore recommended to maintain a balance between the different nutrients and to regularly monitor plant health to avoid nutrient deficiencies or excesses.

7.3. Sowing

The sowing of food legumes can vary depending on the species and growing conditions. The sowing period also varies depending on the species and local climatic conditions. In general, legumes are sown in spring, when temperatures are warm enough to promote germination and growth.

Legumes are generally sown directly in the ground, although some species can be sown in pots or trays for later transplanting.

Seeds are generally sown at a depth of 2 to 3 times the size of the seed, although this may vary depending on the species.

Sowing distances also depend on the species and the cultivation method used. For example, peas can be sown in rows spaced 30 to 40 cm apart, while beans can be sown in rows spaced 50 to 60 cm apart.

Legumes can be sown in association with other crops, such as corn or cucurbits, to benefit from the nitrogen supply provided by atmospheric nitrogen fixation.

To improve germination, it is recommended to maintain constant humidity around the seeds until they emerge. This can be achieved by watering regularly or by using techniques such as drip irrigation.

7.4. Weed Management

Weed management in a food legume crop is important to reduce competition for nutrients, water, and light, which can reduce crop yield. Weed management practices for a food legume crop include:

- Tilling the soil before planting to eliminate existing weeds and prevent their growth.

- Using organic mulch or weed barrier fabric, where possible, to prevent weeds from growing.
- Manually weeding around legume plants to avoid damaging them.
- Using selective herbicides to eliminate weeds without harming legume plants.
- Avoiding planting legumes with already established weeds. Crop rotation can help reduce weed populations.
- Maintaining healthy and fertile soil so that legume plants can grow quickly and compete with weeds.

It is important to note that weed management should be undertaken from the beginning of the food legume crop to reduce their growth and prevent them from becoming a major problem. Weed management is an important practice to ensure a healthy crop and a bountiful harvest of food legumes.

7.5. Pest and Disease Management

Pest and disease management for a food legume crop can be achieved using sustainable agricultural practices such as:

- ✓ ***Crop Rotation:*** As mentioned previously, crop rotation can help prevent diseases and pests by avoiding planting the same crops on the same land each year.
- ✓ ***Use of Resistant Varieties:*** Resistant varieties can help minimize crop losses caused by diseases and pests.
- ✓ ***Weed Management***: Weeds can serve as a haven for pests and diseases. Weed suppression can help minimize the damage caused by these problems.
- ✓ ***Use of Chemical/Biological Products***: Chemical/biological products such as insecticides, fungicides, and herbicides can help control pests and diseases without harming the environment.
- ✓ ***Use of Organic Fertilizers***: Organic fertilizers can help improve the health of legume plants, making them more resistant to diseases and pests.
- ✓ ***Regular Monitoring***: It is important to regularly monitor legume plants for signs of pests and diseases. Regular monitoring can help detect problems early and minimize crop losses.

7.6. Irrigation

Irrigation is an important aspect of food legume cultivation, as these plants need a sufficient amount of water to grow and produce a good harvest. The water needs of legumes vary depending on the species, the growing period, and the climatic conditions. To manage the irrigation of food legumes, one can:

- ***Determining Water Needs***: It is important to understand the water needs of food legumes to determine the frequency and amount of water needed to irrigate the plants. The amount of water needed depends on the size of the plants, the soil texture, the climatic conditions, and the growth stage of the plants.
- ***Avoiding Excess Water***: Excess water can be harmful to food legumes, as it can lead to excessive growth, root rot, and fungal diseases. It is important to monitor the amount of water used to avoid excess water.
- ***Regular Irrigation***: Food legumes require regular irrigation for healthy growth. Irrigation can be carried out by various means, such as drip irrigation, sprinkler irrigation, flood irrigation, and center-pivot irrigation.
- ***Climate Considerations***: Climatic conditions must be taken into account when irrigating food legumes. During periods of high heat and drought, it is important to irrigate more frequently and in greater quantities to meet the plants' water needs.
- ***Using Water Efficiently***: Using water efficiently can help minimize water loss through evaporation and optimize plant irrigation.

In short, the efficient irrigation of a food legume crop relies on understanding the water needs of the plants, regularly monitoring the amount of water used, taking into account climatic conditions, and using water efficiently.

7.7. Harvest

The harvesting of food legumes varies depending on the type of legume. With chickpeas, the harvest takes place when the pods have ripened and the leaves are dry. The plants are then pulled up or cut down, then left in the field for a few days to dry. The pods are then beaten to extract the seeds.

For beans, the harvest of green beans is carried out when the pods are still green and tender. For dry beans, the harvest takes place when the pods have dried on the plants. The plants are then pulled up and left to dry for a few days before being threshed to extract the seeds.

With lentils, the harvest takes place when the plants begin to dry and the seeds have become hard. The plants are then pulled up or cut down, then left in the field for a few days to dry. The seeds are then beaten to extract the lentils.

With fava beans, the harvest takes place when the pods have ripened and the leaves are dry. The plants are then pulled up or cut down, then left in the field for a few days to dry. The pods are then beaten to extract the seeds.

The harvest can be done manually or mechanically, depending on the size of the crop. It is important to harvest food legumes at the right time to avoid any loss of yield or quality.

7.8. Post-harvest processing

Post-harvest processing of legume seeds is a critical process that has a direct impact on the quality and market value of the grains. The main steps in legume seed processing are:

- ***Cleaning***: The seeds must be sorted and cleaned to remove debris such as stones, stems, and plant debris. This step also removes damaged, malformed, or rotten seeds.
- ***Drying***: The seeds must be dried to reduce their moisture content. This will prevent the growth of mold and fungi and extend the shelf life of the seeds. Drying methods include natural sun drying, air drying, and drying in a grain dryer.
- ***Sorting***: The sorted seeds are then classified according to their size, weight, and quality.
- ***Heat treatment***: Heat treatment can be carried out to eliminate insects and other pests that may be present in the seeds. This step is particularly important for seeds that will be stored for an extended period.
- ***Storage***: The seeds must be stored in a cool, dry place to avoid moisture, heat, and insects. The seeds should be stored in clean, airtight cloth or plastic bags to prevent moisture and contamination.
- ***Packaging***: The seeds can be packaged in bags of different sizes to meet consumer needs.

In short, the post-harvest processing of legume seeds is a complex and crucial process that guarantees the quality and food safety of the grains for consumers. Following these basic steps ensures the quality and food safety of legume grains.

Chapter 4: Forage Crops

Chapter 4: Forage Crops

1. Introduction

1.1. Definition

Forage crops (Fig. 34) are plants cultivated for feeding livestock. They can be used in the form of hay, straw, silage, or pasture.

Forage is mainly composed of herbaceous prairie plants, primarily grasses and secondarily legumes, but many other plant species are cultivated for feeding herbivorous domestic animals and fall into the category of forage plants.

Cereals like barley, oats, and maize are often used as forage crops in many countries, including Europe, North America, and Asia.

Clover and alfalfa are also very popular as forage crops worldwide. They are rich in protein and are often used to feed cattle, sheep, and horses.

In Australia and New Zealand, the most common forage crops are tall fescue and ryegrass. In sub-Saharan Africa, forage crops often include forage sorghum and millet. In South America, natural pasture is often used for livestock, but forage crops like soybeans, maize, and sunflower can also be used. In India, green forage is often cultivated to feed livestock, and common forage crops include alfalfa, clover, sorghum, millet, and wheat. Fodder beet and field pea are also used as forage plants, as well as brome, orchardgrass, and fescue.

1.2. Different Forage Production Areas

Global forage crop production depends on many factors, such as demand for animal products, land availability, water resources, climate conditions, and agricultural practices. According to FAO data, global forage crop production in 2021 was approximately 5.5 billion tonnes of dry matter.

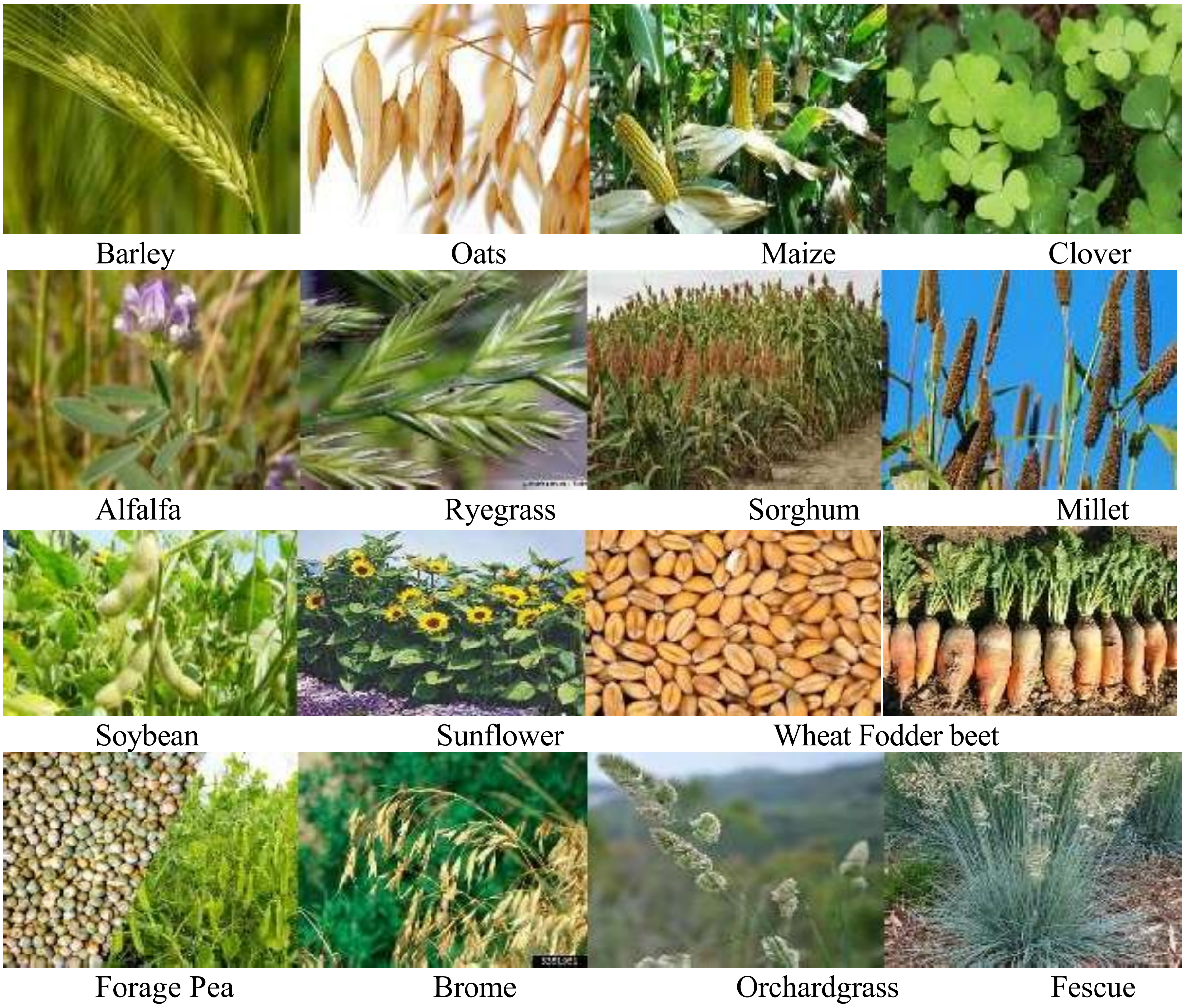

Figure 34 : Main forage crops used in the world.

The Evolution of Forage Crop Production in Recent Years Is Illustrated in Figure 35.

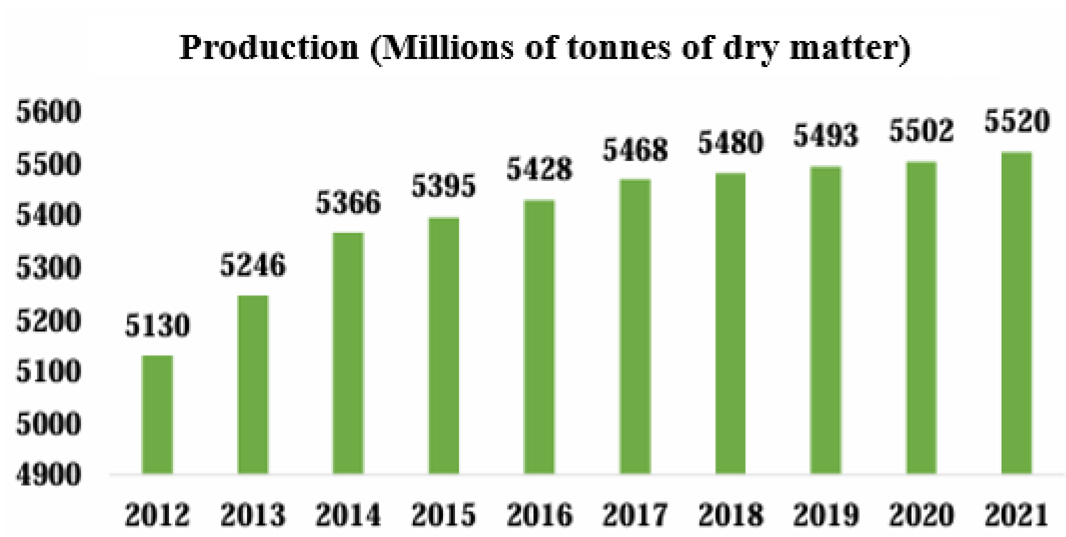

Figure 35: Evolution of forage crop production in the world (FAO, 2021).

These figures show a slight increase in forage crop production over the last decade. This can be attributed to a growing demand for animal products worldwide, as well as improved productivity and efficiency of livestock systems and agricultural practices. However, it should be noted that the impacts of climate change and other factors can also affect forage crop production worldwide.

The main forage crop producing countries in the world are China in first place worldwide, followed by the United States and Brazil (Fig. 36). We can also note the strong presence of South American countries, such as Brazil and Argentina, as well as European countries, such as France, Spain, and Germany, among the main producers.

- ✓ *China* : China is the largest producer of forage crops in the world, with production estimated at around 800 million tonnes of dry matter in 2020. The main forage crops in China are maize, alfalfa, faba bean, and forage sorghum.
- ✓ *The United States*: The United States is the second largest producer of forage crops, with an estimated production of about 650 million tons of dry matter in 2020. The main forage crops in the United States are corn, barley, wheat, and soybeans.
- ✓ *Brazil*: Brazil is the third largest producer of forage crops, with an estimated production of about 450 million tons of dry matter in 2020. The main forage crops in Brazil are corn, soybeans, and sorghum.
- ✓ *India*: India is the fourth largest producer of forage crops, with an estimated production of about 350 million tons of dry matter in 2020. The main forage crops in India are corn, sorghum, millet, and fodder rice.
- ✓ *Russia*: Russia is the fifth largest producer of forage crops, with an estimated production of about 250 million tons of dry matter in 2020. The main forage crops in Russia are oats, triticale, ryegrass, and rye.

In summary, the area of forage crop production in the world is very large, with more than 1.515 billion hectares in total, including an area of 775 million hectares for annual forage crops and 740 million hectares of permanent forage crops.

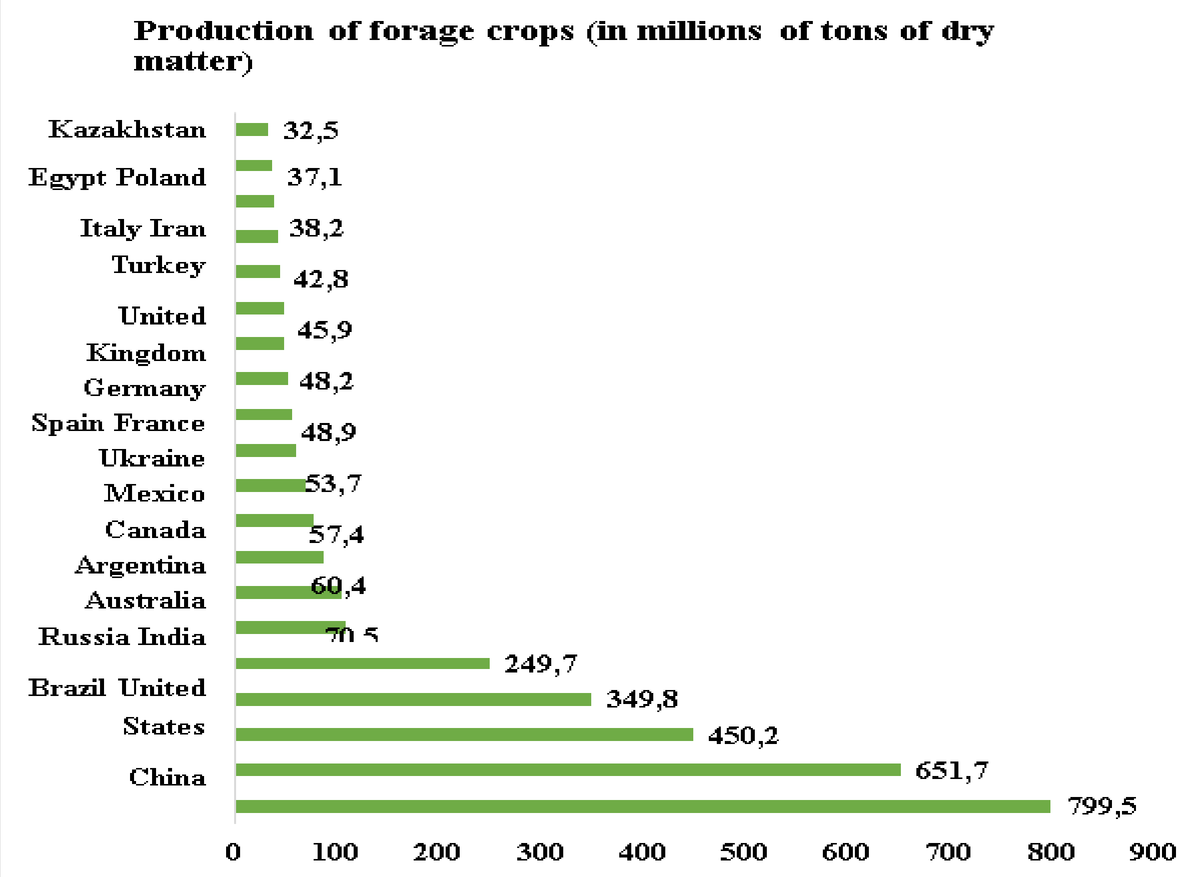

Figure 36: The main forage crop producing countries in the world (FAO, 2021).

There are regional differences in forage crop types and agricultural practices. For example, in Europe and North America, pastures and permanent forage crops are more common, while in South America and Asia, annual forage crops are more widespread. Both annual and permanent forage crops are important, with regional differences in the types of forage crops used.

1.3. Situation in Algeria.

According to FAO data, forage crop production in Algeria is about 18 million tons per year. The main forage crops produced in Algeria are forage cereals such as barley and oats, as well as alfalfa. These crops are used to feed livestock, including sheep, goats, and cattle.

However, forage crop production in Algeria faces challenges such as water scarcity, drought, soil degradation, and a lack of financial resources to invest in modern agricultural technologies. Consequently, Algeria must import significant quantities of fodder to meet the needs of its livestock.

To address this situation, Algeria has launched programs to improve water management and develop more sustainable agricultural techniques, such as conservation agriculture and drip irrigation. In addition, the Algerian government has encouraged farmers to use more drought-resistant forage crops, such as alfalfa and forage legumes.

Forage crop production in Algeria is relatively stable, with a slight increase since 2011 (Fig. 37).

The area of forage crop production in Algeria has also seen a slight increase over the last decade. It has increased from 5.1 million hectares in 2010 and 2011 to 5.4 million hectares from 2018 to 2020. However, this area remains insufficient to meet the needs of livestock in Algeria, forcing the country to import significant quantities of fodder.

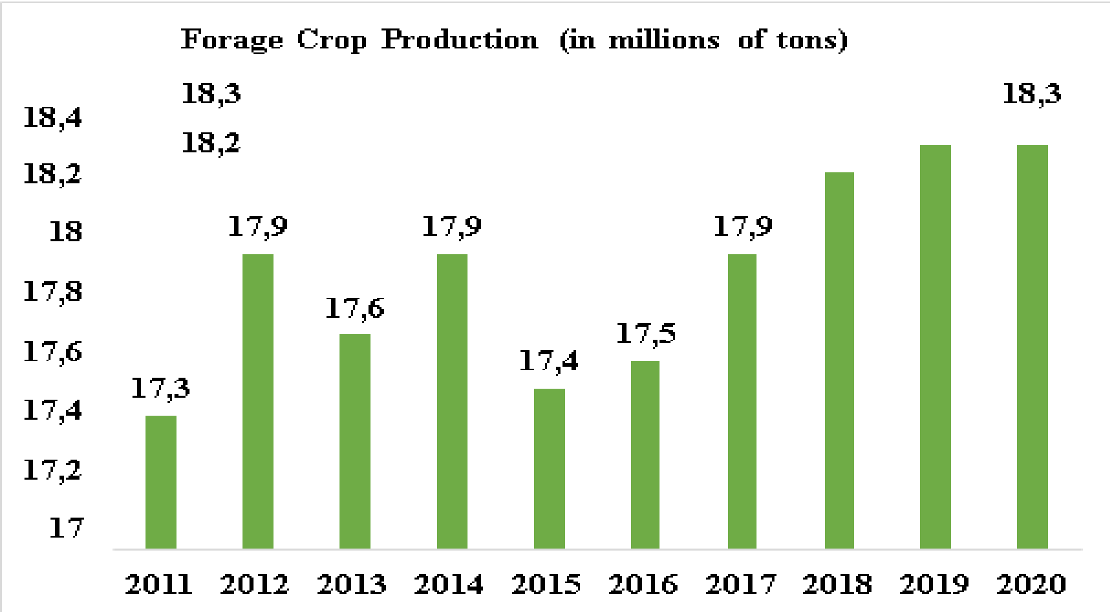

Figure 37: Evolution of forage crop production in Algeria from 2011 to 2020 (FAO, 2021).

According to the agricultural statistics published by the Ministry of Agriculture and Rural Development in Algeria for the year 2020, the main forage crops produced in Algeria are the following:

- Alfalfa: 2.06 million tons;
- Forage Maize: 1.8 million tons;
- Oats: 1.04 million tons;
- Forage Sorghum: 784,000 tons;
- Hay: 702,000 tons.

Forage crop production areas in Algeria vary depending on many factors such as climate, soil type, topography, irrigation, and agricultural practices. The main forage crop production areas in Algeria are:

- *The High Plains*: The main forage crops produced in this region are alfalfa, oats, and clover.
- *The High Plateaus*: The most common forage crops in this region are oats, barley, maize, and alfalfa.
- *The Oases and the desert*: These areas are located in the desert regions of southern Algeria and are irrigated by groundwater sources. Forage crops produced in these areas include alfalfa, sorghum, and maize.
- *The coastal regions*: The coastal regions of Algeria have a Mediterranean climate and produce a variety of forage crops, including alfalfa, maize, and clover.

It is important to note that these production areas are not exclusive and that some crops can be produced in different regions depending on climatic conditions and agricultural practices.

There are several types of forage crops that can be grown in Algeria, including:

- *Legumes*: Forage crops in this category include clover, alfalfa, vetch, lupin, broad bean, peas, and beans. Legumes are rich in protein and can contribute to nitrogen fixation in the soil.
- *Cereals*: Forage crops in this category include maize, sorghum, oats, and barley. Cereals are rich in energy and carbohydrates.
- *Grasses*: Forage crops in this category include ryegrass, fescue, orchardgrass, bromegrass, rye, and temporary grassland. Grasses are rich in fibers and can contribute to digestion in animals.
- *Perennial forage crops*: Forage crops in this category include alfalfa, clover, and sainfoin. These crops have a longer lifespan than annual crops and can provide feed for several years.
- *Annual forage crops*: Forage crops in this category include forage maize, forage sorghum, oats, and wheat. These crops are grown annually and can provide feed for one growing season.

2. Some data on the exploitation and conservation of forage

2.1. Exploitation

The exploitation of forage crops is an agricultural practice that aims to cultivate plants to feed livestock, including cattle, sheep, goats, and horses. Forage crops can be used fresh or preserved for later use. Among the practices that allow the exploitation of forage crops:

- ✓ ***Crop selection***: Farmers choose forage crops based on their characteristics, adaptability to local conditions, and nutritional value for animals. Common forage crops include clover, alfalfa, oats, orchardgrass, ryegrass, and maize.
- ✓ ***Soil preparation***: Before sowing forage crops, the soil is prepared according to the specific needs of each plant. Preparation may include plowing, soil leveling, adding fertilizer, and weed management.
- ✓ ***Sowing***: Forage crops are sown at the optimal time, usually in spring or autumn, depending on the climatic conditions and growth cycles of each plant. Sowing can be done by hand or using a machine.
- ✓ ***Maintenance***: Forage crops require regular care, such as watering, fertilization, and weed management, to maximize their growth and yield.
- ✓ ***Harvesting***: Forage crops can be harvested at different stages of their growth, depending on their intended use. Harvests can be fresh or preserved for later use as hay, silage, or other preservation methods.

Forage exploitation depends on the type of forage and the cultivation method used. General practices that can be applied to exploit forage are:

 Manage pastures: If the forage is grown outdoors, it is important to manage pastures well to ensure healthy and consistent plant growth. This may include rotating pastures to allow plants to regenerate and avoid overgrazing.

 Harvest at the right time: If the forage is harvested for later use, it is important to harvest the plants at the optimal stage of their growth to ensure maximum nutritional quality. Harvest time depends on the type of forage, but in general, it is recommended to harvest plants before they flower.

 Use the right preservation techniques: Forage preservation techniques, such as haymaking, ensiling, or baling, vary depending on the type of forage and local climatic conditions. It is important to use the appropriate techniques to ensure optimal nutrient preservation.

 Store forage correctly: If forage is stored for later use, it is important to store it correctly to avoid losses in nutritional quality. This may include storing forage in well-ventilated buildings or under waterproof tarpaulins to protect it from the weather.

 Ensure a balanced diet: Forage is often only part of the diet of livestock. It is important to supplement the diet with additional feeds, such as cereals, concentrates, or mineral supplements, to ensure a balanced diet and optimal animal growth.

2.2. Preservation

Forage preservation is essential to ensure a quality food supply throughout the year for livestock. The most commonly used preservation techniques are haymaking, ensiling, and baling.

2.2.1. Hay

Hay is a type of dry forage that is produced by drying cut grass. Farmers cut the grass a few centimeters above the ground, let it dry, and then bale it for storage (Fig. 38). Hay can be made from different varieties of grass, such as alfalfa, clover, oats, rye, wheat, or ryegrass.

Hay is an important source of food for livestock, such as horses, cattle, sheep, and goats. It can be given to these animals throughout the year, as it can be stored for months or even years if stored properly. Hay can also be used for animal bedding, as it is absorbent and can help maintain a clean and dry environment.

The quality of hay depends on several factors, including the variety of grass used, the harvest period, the weather conditions during harvest, the drying method, and the storage method. To obtain high-quality hay, it is important to harvest the grass at the right time, when the nutrient content is highest, to dry the grass quickly to prevent degradation and mold, and to store the hay in a dry, well-ventilated place to prevent moisture and deterioration.

Figure 38: Hay.

2.2.2. Silage

Silage is a method of forage preservation that involves fermenting fresh, moist plants under anaerobic (airless) conditions to preserve their nutritional value. This technique allows nutrient-rich forages such as grass, corn, clover, and alfalfa to be stored for several months or even a whole year while maintaining their quality and nutritional value.

The ensiling process begins with cutting the plants, which are then chopped into small pieces to facilitate compaction in a silo or trench. The plants are then packed and pressed to remove air and promote anaerobic fermentation (Fig. 39). Lactic acid bacteria naturally present on fresh plants grow and produce lactic acid, which acidifies the environment and kills undesirable bacteria. This acidifying fermentation also helps to preserve the nutritional quality of the plants, especially the protein content.

Silage can be used to feed different types of animals, such as cattle, sheep, goats, and pigs. It is particularly useful for farmers who need to store large quantities of fodder to feed their animals during periods of low forage production, such as winter.

Silage can be stored in concrete silos, trenches, plastic bags, or bales wrapped in plastic.

Figure 39: Steps in silage making

2.2.3. Baling

Baling is a method of forage conservation that involves compressing cut plants into a compact form, usually in the shape of a round or rectangular bale, to facilitate storage and transport (Fig. 40). This method is mainly used for hay, but it can also be used for other types of forage, such as straw or crop residues.

The baling process begins with the cutting of the grass or hay, which is then dried until it reaches an optimal moisture content for preservation. The grass is then gathered into a pile, then compressed by a baler to form a dense bale. Bales can vary in size, from small formats of a few kilograms to larger formats of several hundred kilograms.

Figure 40: Baling of forage.

Baling offers several advantages in terms of forage storage and transport. Bales are easier to store than loose grass, as they can be stacked and stored in a smaller space. Furthermore, bales can be easily transported on trailers or trucks, which is particularly important for farmers who buy or sell forage.

However, baling can also have disadvantages. Bales can be more expensive to produce than bulk storage, as purchasing or renting a baler may be necessary. In addition, bales can be more difficult to handle than loose grass, as they can be heavy and require specific handling equipment for their movement.

In general, baling is an effective method of forage conservation, suitable for a wide range of animal species and livestock systems.

There are other forage conservation techniques such as:

- ***Tedding*** This technique involves exposing the cut plants to the sun and wind to dry them. This method is commonly used for hay crops. Tedding accelerates the drying of the plants and can improve the quality of the hay by reducing the moisture content.
- ***Barn drying***: This method involves drying the plants in a barn or other enclosed, well-ventilated area. The plants are arranged on a flat surface and are turned regularly to ensure uniform drying. This method is often used for hay crops and can allow for better forage conservation than tedding.
- ***Refrigeration*** This method involves storing forage at low temperatures to slow the growth of bacteria and mold. This technique is commonly used for highly perishable animal feed, such as rapeseed and flax.
- ***Freezing:*** Freezing is an effective method for preserving forage for a long period. This

technique involves storing the plants in a freezer or cold storage facility to slow the growth of bacteria and mold. Freezing can be used to preserve a wide variety of forages, including hay, grass, and legume crops.

- ***Chemical Treatment:*** Some chemical substances, such as propionic acid, can be added to forage to inhibit the growth of bacteria and mold. This method is often used for corn silage and can improve the nutritional quality of the forage.

It is important to choose the preservation technique best suited to each type of forage and each situation, depending on the available resources, the preservation objective, and the desired nutritional quality.

3. Forage Crops

3.1. Associations (definition and some examples)

Forage crop associations are a common practice in agriculture to maximize crop productivity and quality. Forage crop associations involve sowing two or more plant species together in the same field. The benefits of this practice are multiple:

- Improved nutritional quality of animal feed, thanks to a better distribution of nutrients in the different plant species.
- Reduction of diseases and pests, as associations can inhibit weed growth, prevent soil depletion, and increase biodiversity.
- Increased productivity, as associations can reduce competition between plants for soil and light resources.

The most common forage crop associations include mixtures of grasses and legumes, such as clover and ryegrass, which provide a balance of nitrogen and fiber, as well as mixtures of annual and perennial plants, such as corn and sorghum, which provide a combination of high yields and nutritional quality. Among the most commonly used forage crop associations are:

 Legumes and Grasses: Legumes, such as clover and alfalfa, are often associated with grasses, such as ryegrass and orchardgrass. Legumes fix atmospheric nitrogen, which benefits grasses by providing a natural nitrogen supply. In return, grasses help support legumes and prevent them from lodging. This association improves the nutritional quality of the forage and overall productivity.

 Cereal and Legume Mixtures: Cereals, such as rye, wheat, oats, or triticale, can be associated with legumes, such as forage peas or vetch. This association increases the nutritional quality of the forage, particularly in terms of protein, and improves resistance to diseases and weeds.

 Cover Crops: Cover crops are plants grown between two main crops, generally during the cold season. Cover crop mixtures can include legumes, grasses, and crucifers (such as rapeseed or forage radish). These associations improve soil cover, reduce erosion, and increase soil organic matter.

 Strip cropping: This method involves sowing different species of forage plants in alternating strips. This approach can improve biodiversity, facilitate harvesting, and offer a habitat for pollinators and natural enemies of pests.

 Agroforestry: Agroforestry is a practice that combines animal husbandry, the cultivation of forage plants, and the planting of trees. The trees provide shade, reduce soil erosion, and improve biodiversity. The animals can feed on the forage crops and trees, and their droppings help fertilize the soil.

Specific forage crop associations depend on the climate, soil, and nutritional needs of the livestock. It is important to choose the appropriate species and manage the crops in a way that maximizes the benefits of the association.

3.2. Forage Grasses: Some Examples

Forage grasses are robust, persistent, and fast-growing. They are well adapted to frequent defoliation by grazing animals. They have a fibrous root system that allows them to withstand heavy grazing pressure. The roots also help prevent soil erosion and improve soil structure.

Forage grasses are often found in mixtures because different grasses have different qualities, growing seasons, and preferred conditions. This helps ensure a continuous supply of forage. Among these grasses forage, we note:

- **Cultivated Oat (*Avena sativa*)**: a grass cultivated for its ability to quickly produce forage and starch-rich grains used for animal and human food. Cultivated oat is an annual plant belonging to the Poaceae family, also known as straw grass because of its hollow stem. It generally measures between 60 and 120 cm in height and has flat, narrow leaves about 30 cm long.

The lower leaves are larger than the upper leaves and often have a slight curvature. Oat ears are panicle-shaped inflorescences, with branched branches that bear flattened spikelets. The spikelets are composed of two to three flowers, each having a membranous ligule and scaly glumes. The flowers themselves are small and generally have six stamens and two stigmas (Fig. 41).

Oats can be sown in autumn or spring and grow well in fertile, well-drained soils. It is generally harvested before flowering, when it is still tender and juicy, for maximum quality as forage.

Figure 41: Cultivated Oat

- **Perennial Ryegrass (*Lolium perenne*)**: is a species of forage grass very common in meadows and pastures in Europe and North America.

It is a perennial grass that forms dense tufts or spreads by stolons and rhizomes. This perennial plant can reach a height of 50 to 100 cm and has narrow, elongated, bright dark green, flat leaves measuring about 2 to 6 mm wide. The leaf sheath is smooth and flattened, and the ligule is present at the base of the leaf. The stems are erect and bear cylindrical spikes of pale green to light brown, which measure 10 to 30 cm long. The roots of ryegrass are taproots and deep, which allows it to withstand drought and absorb nutrients deep in the soil (Fig. 42).

This plant is also very resistant to diseases and pests, making it a species highly valued by breeders. Ryegrass generally flowers from May to July and produces small brown seeds, which are often used for seed production. This plant can be grown in a wide variety of soils, from sand to clay, and thrives in temperate to subtropical climates. It has a rapid growth rate and can produce 2-3 forage harvests per year. It has a high forage yield and high nutritional value, especially if harvested early. It is very resistant to grazing and provides several forage harvests throughout the year.

Figure 42: Ryegrass

- **Orchardgrass (*Dactylis glomerata*)** : a fast-growing perennial grass that provides forage appreciated by animals.

Cock's-foot is a perennial plant belonging to the Poaceae family, also known as orchardgrass or cocksfoot. It can reach a height of 1 to 1.5 meters and has flat, broad leaves about 30 cm long. The leaves often have a prominent midrib and a closed sheath. The cocksfoot spikes are panicle-shaped inflorescences, with branched branches that bear cylindrical spikelets. The spikelets are composed of several florets, each having a membranous ligule and scaly glumes. The flowers themselves are small and generally have three stamens and two stigmas (Fig. 43).

Orchardgrass is widely cultivated as a forage plant for livestock because it is rich in nutrients and produces a large amount of biomass. It is capable of growing in a wide variety of soils, including poor and acidic soils, and is often used for pasture regeneration. Orchardgrass can be harvested several times a year for maximum quality as forage. It tolerates grazing and wet, acidic soils well.

Figure 43: Orchardgrass

- **Red Fescue (*Festuca rubra*)** : a grass often used to establish lawns and turfs. Red fescue is a perennial herbaceous plant belonging to the Poaceae family, also known as sheep fescue. It typically measures 30 to 70 cm in height and has flat, narrow leaves, about 20 cm long. The leaves often have a closed sheath and a membranous ligule. The ears of red fescue are panicle-shaped inflorescences, with branched branches that bear cylindrical spikelets. The spikelets are composed of several florets, each having a membranous ligule and scaly glumes. The flowers themselves are small and generally have three stamens and two stigmas (Fig. 44).

Red fescue is widely cultivated as a forage plant for livestock because it is rich in nutrients and easy to grow. It grows well in well-drained soils and tolerates a wide range of climatic conditions. It is often used for pasture regeneration and hay production. Red fescue can be harvested several times a year for maximum quality as forage. It is also resistant to drought and acidic soils.

Figure 44: Red Fescue

- **Kentucky bluegrass (*Poa pratensis*)**: a very common grass in meadows and pastures. It forms dense tufts with spreading stems and blue-green leaves (Fig. 45). It adapts to a wide variety of soils and climates, from temperate to cold zones. Kentucky bluegrass is very resistant to grazing and regenerates well after forage harvesting. It has a high nutritional value and a palatable taste for animals. It prefers cool soils rich in organic matter and does not thrive in acidic or poor sandy soils. Kentucky bluegrass is often grown in grass mixtures of permanent meadows due to its hardiness and forage value.

Figure 45: Kentucky Bluegrass (*Poa pratensis*)

3.3. Forage Legumes. Some examples.

These are protein-rich plants, making them very interesting forages for feeding herbivores. The proteins contained in legumes are indeed well balanced in essential amino acids.

These are plants that have the ability to fix atmospheric nitrogen thanks to symbiotic bacteria present in their roots. They therefore improve soil fertility.

Most forage legumes are biennial or perennial. They therefore last several years and offer forage harvested several times a year.

These plants have good digestibility, provided they are harvested at the right maturity.

Forage legumes can be used as hay, silage or pasture. They are an excellent base for balanced rations.

Forage legume varieties adapted to all types of soil and climates can be found. Therefore, there are species or varieties for every agronomic situation.

Certain legumes such as birds foot trefoil and vetch can also be used as green manure to improve soil fertility.

Here are some examples of forage Fabaceae (legumes):

- **Clover (*Trifolium sp.*)**: This is one of the main forage species, rich in protein. Clover is a herbaceous plant belonging to the Fabaceae family, also known as legumes. It has basal growth, with short stems and trifoliate leaves, meaning composed of three leaflets. The leaves are often oval or heart-shaped, with serrated edges. Clover flowers are generally pom-pom shaped, with a tubular corolla and five petals, which can be red, white, or pink (Fig. 46).

Clover is highly valued as a forage plant for livestock because it is rich in protein and nutrients. It is also beneficial for soil health, as it can fix atmospheric nitrogen and improve soil fertility. Clover is often used as a cover crop or in crop rotation to improve soil quality.

The most commonly cultivated clover species for animal feed are white clover (*Trifolium repens*), red clover (*Trifolium pratense*), and crimson clover (*Trifolium incarnatum*). Each of these species has specific botanical characteristics, but all are appreciated for their nutritional value and their ability to improve soil quality.

Figure 46: Clover

- **Alfalfa (*Medicago sativa*)** is an excellent forage legume, very rich in protein. It is highly valued for feeding cattle and horses.

Alfalfa is a perennial herbaceous plant belonging to the Fabaceae family, also known as cultivated alfalfa. It generally measures between 30 and 90 cm in height and has leaves composed of three oval leaflets. Alfalfa flowers are grouped in racemes, with purple, blue, or yellow flowers, and banner-shaped petals. Alfalfa pods are thin and slightly curved, measuring about 2 to 3 cm in length. They generally contain two to six seeds, which can be used for seed production for planting new alfalfa crops (Fig. 47). The pods are often harvested before they are fully mature to avoid seed loss. Alfalfa seeds are small and round, measuring about 2 mm in diameter. They are rich in protein, fiber, and nutrients, and can be used for animal and human consumption.

Alfalfa is widely cultivated as a forage plant for livestock because it is rich in protein, fiber, and essential nutrients such as calcium, potassium, and magnesium. It is also beneficial for soil health, as it can fix atmospheric nitrogen and improve soil fertility.

Alfalfa is a perennial crop and can be harvested several times a year, often at the beginning of flowering, for maximum quality as forage. It is also used as a cover crop to improve soil quality and for seed production for animal and human food. Alfalfa is a very important plant for the animal feed industry, especially for dairy farmers. It is also used as a protein source for pet food and as a medicinal plant for its anti-inflammatory and antioxidant properties.

Figure 47: Alfalfa

- **Common vetch (*Vicia sativa*)** is a dual-purpose legume (forage and green manure) that improves soil fertility and provides protein-rich fodder, especially for sheep. Common vetch is an annual herbaceous plant in the Fabaceae family, also known as common vetch. It typically grows from 30 to 90 cm tall and has slender, branched stems. Vetch leaves are composed of several oval leaflets, often with a pointed tip. Vetch flowers are grouped in dense, cylindrical clusters, measuring 4 to 10 cm in length. Each flower has a typically butterfly-shaped corolla, with five petals generally violet in color, but they can also be white or pink. The fruits of the vetch are thin, elongated pods, containing several seeds (Fig. 48).

Vetch is widely cultivated as a forage crop for livestock, as it is rich in protein, fiber, and essential nutrients such as calcium and phosphorus. It is also beneficial for soil health, as it can fix atmospheric nitrogen and improve soil fertility. Vetch is often used as a cover crop to improve soil quality and for seed production for animal feed.

Vetch is a very important plant for the animal feed industry, especially for dairy farmers. It is also used as a protein source for human food, especially in vegetarian and vegan diets.

Figure 48: Vetch

- **The fava bean (*Vicia faba*)** is a legume that can be used as green fodder or dry fodder. It produces a protein-rich fodder appreciated by many herbivores. The fava bean is an annual herbaceous plant in the Fabaceae family, also known as the broad bean. It typically grows from 0.5 to 1.5 meters tall and has erect, branched stems. Fava bean leaves are composed of several oval leaflets, often with a pointed tip. The flowers of the fava bean are grouped in cylindrical clusters, measuring 5 to 10 cm in length, and have a typically butterfly-shaped corolla, with five petals that are white, pink, or purple. The fruits of the fava bean are broad, flat pods, containing several large, rounded seeds (Fig. 49).

Faba bean is widely cultivated as a forage crop for livestock because it is rich in protein, fiber, and nutrients such as iron, calcium, and potassium. It is also beneficial for soil health, as it can fix atmospheric nitrogen and improve soil fertility. Faba bean is often used as a cover crop to improve soil quality and for seed production for animal feed.

Faba bean is also an important food source for humans, particularly in the Mediterranean and Middle Eastern regions, where it is often consumed as soup or puree. Faba bean seeds are rich in protein and fiber, and are also used in the food industry for the production of flour and vegetable proteins.

Figure 49: Faba bean.

- **Forage Pea (*Pisum sativum*)**: Certain pea varieties (forage pea, protein pea) are cultivated for their forage value. They produce a protein-rich fodder, particularly for feeding cattle, sheep, and goats.

The forage pea is an annual plant of the Fabaceae family. It generally measures from 30 to 90 cm in height and has erect and branched stems. The leaves of the forage pea are composed of several oval or heart-shaped leaflets, with tendrils that help the plant climb. The flowers of the forage pea are butterfly-shaped, generally white or pink, and are grouped in clusters of 2 to 5 flowers. The fruits of the forage pea are elongated pods, containing several round and smooth seeds, green, yellow, or beige in color (Fig. 50).

Forage peas are widely cultivated as a fodder crop for livestock because they are rich in protein, fiber, and nutrients such as iron, calcium, and potassium. It is also beneficial for soil health, as it can fix atmospheric nitrogen and improve soil fertility. Forage peas are often used as a cover crop to improve soil quality and for seed production for animal feed.

Figure 50: Forage Pea

- **Bird's-foot Trefoil (*Lotus corniculatus*)** is a forage legume that can constitute good pastures. It is adapted to many soil types and rich in protein.

Bird's-foot trefoil is a perennial herbaceous plant of the Fabaceae family, also known as bird's-foot deervetch or common bird's-foot trefoil. It generally measures from 10 to 50 cm in height and has erect and branched stems. The leaves of bird's-foot trefoil are composed of several oval leaflets, with serrated edges. The flowers of bird's-foot trefoil are yellow and pompom-shaped, grouped in dense clusters. Each flower has a typically butterfly-shaped corolla, with five petals. The fruits of bird's-foot trefoil are curved, crescent-shaped pods, containing several seeds (Fig. 51).

Bird's-foot trefoil is widely cultivated as a forage crop for livestock because it is rich in protein, fiber, and nutrients such as calcium, phosphorus, and magnesium. It is also beneficial for soil health, as it can fix atmospheric nitrogen and improve soil fertility. Bird's-foot trefoil is often used as a cover crop to improve soil quality and for seed production for animal feed.

Figure 51: Bird's-foot Trefoil

3.4. Forage Trees and Shrubs

Forage trees and shrubs are plants that are used to feed livestock such as cows, goats, sheep, horses, pigs, rabbits, chickens, and turkeys. They are often grown in pastures or paddocks to provide an additional food source for the animals.

3.4.1. Benefits

Forage trees and shrubs can provide several important benefits to agriculture and livestock farming, including:

- *Providing a source of fodder*: Forage trees and shrubs can provide a food source for animals during periods of fodder shortage, such as during droughts or harsh winters.
- *Improving soil quality*: The roots of forage trees and shrubs can help fix atmospheric nitrogen in the soil, thus improving soil fertility and structure. Fallen leaves and branches can also contribute to enriching the soil with organic matter.
- *Reducing erosion*: Forage trees and shrubs can help prevent soil erosion by stabilizing slopes and reducing the impact of rainfall.
- *Provide habitat for wildlife*: Fodder trees and shrubs can provide habitat for a variety of animals, including birds, insects, and small mammals.
- *Increase crop diversity*: Fodder trees and shrubs can be grown in association with other crops, such as cereals or vegetables, thus increasing crop diversity and the resilience of the agricultural system.
- *Reduce production costs*: Fodder trees and shrubs can reduce production costs for farmers by providing a food source for animals without the need to purchase additional feed.
- They provide shade and coolness in summer, which improves animal comfort.
- The wood produced can also be used as timber, fuelwood or for making charcoal.

3.4.2. Some examples

There are several species of trees and shrubs used as fodder plants for livestock such as:

- **The carob tree (*Ceratonia siliqua*)**: the carob tree is widely cultivated in Algeria for its pods rich in sugars and nutrients, which are used as animal feed. The leaves and branches can also be used as fodder.

The carob tree is a tree of the Fabaceae (or Leguminosae) family native to the Mediterranean basin; it can reach up to 15 meters in height. Its bark is rough and greyish. Its leaves are evergreen, leathery and a shiny dark green. They are composed of 6 to 10 pairs of oval leaflets. Its flowers are small and reddish-brown. They are grouped in dense spikes 10 to 20 cm long. Its fruits are elongated and curved pods, dark brown to black in color, measuring 10 to 30 cm long. Each pod contains numerous smooth, hard seeds, called carobs (Fig. 52). Carobs are rich in sugars (mainly sucrose) and nutrients, making them a valuable food for livestock. The seeds are surrounded by a dark brown, sweet and floury pulp. This pulp, called carob pulp, is rich in sugars, fiber and minerals, making it a quality feed for livestock.

As a fodder plant, the carob tree is particularly appreciated for its pods and pulp, which can be collected, dried and used as a food source for livestock, especially ruminants such as cows, goats and sheep. The leaves and branches can also be used as fodder, although they are less nutritious than carob pulp.

Figure 52: Carob tree

- **Esparto grass (*Stipa tenacissima*)**: Esparto grass is a woody grass that grows in the arid and semi-arid regions of Algeria. It is used as a fodder plant for cattle, sheep and goats.

Esparto grass is a species of perennial woody grass of the Poaceae (or Gramineae) family, native to the arid and semi-arid regions of the Mediterranean basin. It can reach up to 1.5 meters in height. It has a very developed root system, with taproots that can reach 4 to 5 meters deep. Its stems are erect, rigid and Woody at the base, with narrow and elongated leaves. Alfa produces inflorescences in the form of loose panicles, measuring 15 to 30 cm long. The flowers are beige to pale yellow. Its fruits are achenes (indehiscent dry fruits) bearing a long, feathery awn (Fig. 53).

As a forage plant, alfa is very nutritious and appreciated for its high protein, fiber, and mineral content. It is commonly cultivated for livestock, especially for dairy cows. Alfa can be harvested several times a year and is often used for hay, pasture, and silage.

Figure 53: Alfa

- **The Barbary fig (*Opuntia ficus-indica*)**: the Barbary fig is a cactus cultivated in Algeria for its edible fruits rich in sugars and nutrients. The leaves can also be used as forage for animals.

The prickly pear cactus is a cactus of the Cactaceae family native to Mexico, but now widely cultivated in arid and semi-arid areas of many countries, including Algeria. The prickly pear has a fleshy, flattened stem called a cladode that resembles a leaf. The cladodes are oval to rounded and measure 30 to 50 cm long. The cladodes are covered with small spines and fine hairs. The prickly pear produces large, showy flowers of yellow, orange, or red. The flowers measure 7 to 10 cm in diameter. The fruits of the prickly pear are globose berries that measure 5 to 10 cm long. The fruits are edible and have a juicy and sweet pulp of red or yellow color, with a thick skin and spines (Fig. 54).

The cladodes of the prickly pear are used as a forage plant for livestock. They are rich in fiber and minerals such as calcium, phosphorus, and potassium. The cladodes are often cut into small pieces and dried to be used as livestock feed during periods of drought.

Figure 54: Prickly Pear Cactus

- **The date palm (*Phoenix dactylifera*)**: the date palm is an emblematic species of Algerian agriculture, widely cultivated for its sweet fruit. The leaves can also be used as forage for animals.

The date palm can reach a height of 20 to 25 meters, with a solid and robust trunk that can reach a diameter of 70 centimeters. It has feather-shaped leaves, which can measure up to 6 meters in length (Fig. 55). It is a dioecious plant species, meaning that there are distinct male and female individuals. Male and female flowers are found on different palm trees, although hermaphrodite cultivars also exist.

Male flowers develop in clusters along the lower branches of the tree and produce pollen that is carried by wind or insects to female flowers for pollination. Female flowers develop on higher branches and produce fruits, the dates, after being pollinated.

Figure 55: Date Palm

As a forage plant, the date palm is mainly used for its leaves, which are rich in nutrients and fiber. Date palm leaves can be cut and dried to be used as fodder. They are often used to feed livestock during periods of drought when other food sources are scarce.

The leaves of the date palm have a high content of protein, fiber, and minerals such as calcium, phosphorus, and potassium. They also contain phenolic compounds and antioxidants, which can help protect livestock from diseases.

In addition to its leaves, the date palm can also be used as a source of fodder for animals with its stems, unripe fruits, and harvest waste. However, it is important to note that the date palm is a relatively expensive plant to cultivate, which can limit its availability as a fodder source for livestock.

- **The wild jujube (*Ziziphus lotus*)**: the jujube is a small tree cultivated in Algeria for its edible fruit rich in sugars and nutrients. The leaves can also be used as forage for animals.

The wild jujube is a small thorny tree or shrub widespread in the arid and semi-arid regions of North Africa, the Middle East, and Central Asia. The wild jujube has an average height of 2 to 5 meters and slow growth. It has oval, dark green, and shiny leaves, and small yellow flowers that appear in summer. The fruits, called jujubes, are small, round, and fleshy, and have a color ranging from light yellow to dark red (Fig. 56).

Jujubes are rich in nutrients such as fiber, vitamins, minerals, and antioxidants, making them a nutritious food source for livestock. Jujubes can be eaten fresh or dried and can be used as a food supplement for animals during periods of food shortage.

As a forage plant, the wild jujube can also provide shade and shelter for livestock, as well as water sources for wild animals and birds. However, it is important to note that the wild jujube has sharp thorns that can cause injuries to animals and humans (Fig. 56).

Figure 56: Wild Jujube

- **Tamarisk (*Tamarix spp.*)**: Tamarisk is a drought-resistant shrub or small tree that grows in the arid and semi-arid areas of Algeria. It is used as a forage plant for cattle, sheep, and goats. It is used as a forage plant for livestock in some parts of the world.

Tamarisk has an average height of 2 to 10 meters and rapid growth. It has thin, leafy branches, with tiny leaves and pale pink or white flowers that appear in summer. The fruits are small capsules containing many seeds (Fig. 57).

As a forage plant, tamarisk is used for its leaves and young shoots, which are rich in nutrients such as proteins, fiber, minerals, and antioxidants. The leaves can be consumed fresh or dried, and can be used as a food supplement for animals during periods of food shortage.

Tamarisk is also used as a dune fixation plant and for the regeneration of depleted soils. It is able to tolerate saline soil conditions and drought, making it a useful plant for the restoration of coastal ecosystems.

Figure 57: Tamarisk

- **Mastic Tree (*Pistacia lentiscus*)**: The mastic tree is a shrub that grows in many regions of Algeria. It is sometimes used as a forage plant for livestock.

The mastic tree has an average height of 2 to 5 meters and slow growth. It has persistent, leathery, and shiny leaves, which are composed of several leaflets. The flowers are small and green and appear in spring. The fruits are reddish berries containing a single seed (Fig. 58).

Figure 58: Mastic Tree

As a forage plant, the mastic tree is used for its leaves and young shoots, which are rich in nutrients such as proteins, fibers, and minerals. The leaves can

be consumed fresh or dried, and can be used as a food supplement for animals during periods of food shortage.

- **The Phoenician Juniper (*Juniperus phoenicea*):** The Phoenician juniper is a drought-resistant tree or shrub that grows in the semi-arid regions of Algeria. It is used as a forage plant for cattle and sheep in some parts of the world. The Phoenician juniper has an average height of 2 to 5 meters and slow growth. It has thorny branches, with needle-shaped leaves and cone-shaped fruits. The cones are small, spherical, and dark blue when ripe (Fig. 59).

As a forage plant, Phoenician juniper is used for its leaves and young shoots, which are rich in nutrients such as protein, fiber, and minerals. The leaves can be consumed fresh or dried, and can be used as a food supplement for animals during periods of food shortage.

Figure 59: Phoenician Juniper

- **Sage-leaved Rockrose (*Cistus salviifolius*):** The sage-leaved rockrose is a small shrub that grows in the arid and semi-arid areas of Algeria. It is used as a forage plant for cattle and sheep in some parts of the world.

The sage-leaved rockrose has an average height of 0.5 to 2 meters and rapid growth. It has tough, persistent leaves, which are grey-green and have an elongated oval shape, with slightly toothed edges. The flowers are large and white, with a bright yellow center and red stamens (Fig. 60).

Figure 60: Sage-leaved Rockrose.

As a forage plant, the sage-leaved rock-rose is used for its leaves, which are rich in nutrients such as protein, fiber, and minerals. The leaves can be consumed fresh or dried, and can be used as a food supplement for animals during periods of food shortage.

3.5. Permanent Grasslands (Importance, Situation and Use)

Permanent grasslands are grassy areas that have not been cultivated for more than 5 years.

They play an important role:

- ***Economic:*** They are a source of fodder for livestock. Permanent grasslands produce hay and pasture for animals. It is a low-cost fodder production.
- ***Environmental:*** Permanent grasslands contribute to biodiversity by providing a habitat for many animal and plant species. They also participate in the protection of soils against erosion, the regulation of the water cycle and carbon sequestration.
- ***Landscape:*** Permanent grasslands contribute to the quality of the rural landscape.

Permanent grasslands are used to produce fodder in the form of hay or grazed grass. Extensive or intensive grazing can be practiced there. Some grasslands can also be mown to produce silage or pellets. The productivity of permanent grasslands depends on several factors such as botanical composition, fertilization and soil and climate conditions.

In Algeria, permanent grasslands play a very important role, especially for sheep and cattle farming. Their area is estimated at about 9 million hectares, which represents 9% of the usable agricultural area.

Algerian natural grasslands are mainly located in the steppe zone, in the high plateaus and mountains. Different types of grasslands can be found there:

- Natural grasslands with annual and perennial grasses (such as the poppy) and legumes (clover, alfalfa). They are rich in species and very productive.
- Alfa (*Stipa tenacissima*) steppes, a perennial grass. These are lower quality grazing lands, but they play a role in preventing erosion.
- Mountain grasslands, more humid, with fescues and bentgrass. They are grazed in summer.
- Floodplain meadows along wadis, with reeds, rushes and bulrushes. These are winter grazing areas.

These grasslands are subjected to high grazing pressure, which leads to vegetation degradation and erosion problems. Their improvement and preservation are an important issue in Algeria, which requires better grazing practices and appropriate fertilization.

The use of grasslands in Algeria is mainly through direct grazing of animals, especially sheep and cattle. A small part is mowed to produce hay. Grasslands form the basis of the diet of herbivores in Algeria, hence their socio-economic importance.

3.6. Rangelands (forest, steppe, pre-Saharan and Saharan zones)

Forage rangeland in Algeria varies considerably depending on the different ecological zones of the country. The types of forage rangelands that can be found in the different zones are:

- ✓ ***Forest zones:*** Forage rangelands in forest zones consist of natural grasslands, moors and open and dense forests. The most common forage species are clover, cocksfoot, alfalfa, fescue and ryegrass.
- ✓ ***Steppe zones:*** Forage rangelands in steppe zones consist of herbaceous steppes, bushes and scrubland. The most common forage species are alfa, thistle, thyme, rosemary and juniper.
- ✓ ***Pre-Saharan zones:*** Forage rangelands in pre-Saharan zones consist of arid steppes, sand dunes and rocks. The most common forage species are alfa and dwarf palm.
- ✓ ***Saharan zones:*** Forage rangelands in Saharan zones are very limited and consist mainly of oasis areas, where forage crops such as alfa, dwarf palm and sorghum are grown.

It is important to note that forage rangelands in Algeria are subject to significant anthropogenic pressures, including overgrazing, deforestation and desertification, which have a negative impact on the quality and quantity of forage species available for livestock.

Chapter 5: Industrial crops

Chapter 5: Industrial crops

1. General Information

Industrial crops are agricultural crops intended for the production of raw materials for industry, such as biofuels, textile fibers, chemical products, animal feed, and construction materials.

Most are cultivated by large agro-industrial farms (soybeans, corn, cotton, etc.) or by semi-industrial companies (coffee, cocoa, tea, oil palm).

1.1. Agroeconomic Importance

Industrial crops have great agroeconomic importance in many countries, as they are often cultivated to meet the growing demand for raw materials for industry and for export.

Examples:

- ***Corn***: cultivated in many countries, notably the United States, China, Brazil, and Argentina, corn is an important crop for the production of biofuels, animal feed, and chemical products. It is also an important source of income for farmers and exporters in these countries.
- ***Soybeans***: cultivated primarily in Brazil, Argentina, the United States, and China, soybeans are an important crop for the production of vegetable oil, animal feed, and chemical products. It is also an important source of income for farmers and exporters in these countries.
- ***Cotton***: cultivated primarily in India, China, the United States, and Pakistan, cotton is an important crop for the production of textile fibers and chemical products. It is also an important source of income for farmers and exporters in these countries.
- ***Sugarcane***: cultivated mainly in Brazil, India, China, and Thailand, sugarcane is an important crop for the production of sugar, ethanol, and chemical products. It is also an important source of income for farmers and exporters in these countries.
- ***The oil palm***: cultivated primarily in Indonesia and Malaysia, the oil palm is an important crop for the production of vegetable oil, animal feed, and chemicals. It is also an important source of income for farmers and exporters in these countries.

These industrial crops can contribute significantly to the economies of many countries, but their impact on the environment and the sustainability of their production must be taken into account to avoid negative effects on ecosystems and local communities.

1.2. History

Industrial crops have a long history dating back to the Industrial Revolution of the 18th century in Europe. This period saw the emergence of new technologies and new industries that stimulated the demand for agricultural raw materials for the production of textiles, paper, chemical products, and other manufactured goods.

Over time, industrial crops have evolved to meet the growing needs of industry, and new crops have been introduced to exploit previously uncultivated land. For example, sugarcane was introduced to South America and the Caribbean to meet the growing demand for sugar in Europe, while cotton was introduced to India and Africa to meet the growing demand for textiles.

In the 20th century, governments began to encourage the production of industrial crops to stimulate exports and economic growth. Policies such as the "Green Revolution" in India and the "Grain Revolution" in Mexico encouraged the adoption of new agricultural practices and the use of high-yielding seeds to increase the production of crops such as rice and wheat.

However, the expansion of industrial crops has also had negative effects on the environment and local communities, such as soil degradation, deforestation, water pollution, and biodiversity loss. Over time, governments and international organizations have begun to promote more sustainable agricultural practices to reduce these negative impacts while continuing to meet the needs of industry.

1.3. Technical Classification

Industrial crops can be classified in different ways depending on their use and production method as follows:

1.3.1. Classification by Use

- ***Food Crops***: crops intended for human and animal consumption, such as corn, soybeans, etc.
- ***Non-Food Crops***: crops intended for the production of biofuels, fibers, pharmaceuticals, cosmetics, chemical products, and other industrial products, like sugarcane, cotton, oil palm, tobacco, etc.

1.3.2. Classification according to the production method

- ***Conventional industrial crops***: crops produced on a large scale using intensive agricultural techniques, such as the use of chemical fertilizers, pesticides, agricultural machinery, and irrigation.
- ***Sustainable industrial crops***: crops produced using sustainable agricultural practices that minimize negative impacts on the environment, such as crop rotation, agroforestry, water management, and biodiversity protection.
- ***Organic industrial crops***: crops produced without the use of synthetic chemicals, using organic farming techniques to improve soil health and biodiversity, such as composting, biological pest control, and crop rotation.

1.3.3. Classification according to the production area

- ***Large-scale industrial crops***: crops produced on a large scale in specialized agricultural areas, such as cereal plains, cotton production regions, etc.
- ***Small-scale industrial crops***: crops produced on small plots of land in rural areas, such as family gardens, food crops, etc.

These classifications may vary depending on the country and region, but they provide a basis for understanding the different categories of industrial crops.

2. Examples of industrial crops

2.1. Sugar beet

Sugar beet is an herbaceous plant belonging to the Chenopodiaceae family.

2.1.1. Biology

Sugar beet is a biennial plant that is usually cultivated as an annual crop. It can reach a height of 1 to 2 meters and produces a fleshy taproot that contains a large amount of sugar. The leaves are large, green, and heart-shaped, and can reach a length of 30 to 50 cm (Fig. 61). Sugar beet is a self-pollinating plant, meaning that it pollinates itself. The flowering of the plant usually occurs in the second year of cultivation, but it is often suppressed to allow for greater root production.

2.1.2. Ecological Requirements

Sugar beet needs a temperate climate with average temperatures of about 15 to 20°C during the growing season. It also requires well-drained, deep, and fertile soil with a pH between 6 and 7.5. Regular watering is important for optimal production of sugary roots.

2.1.3. Technical Production Itinerary

- ✓ Sugar beet cultivation begins with soil preparation, which must be well plowed and leveled.
- ✓ The seeds are generally sown in rows at a depth of 2 to 3 cm and at a distance of 20 to 30 cm between each plant.
- ✓ Cultivation requires regular care such as watering, weeding, fertilization, and pest and disease control.
- ✓ The sugar beet harvest generally takes place between September and November, when the roots have reached their maximum maturity and their sugar content is highest.
- ✓ The roots are extracted from the soil using a special machine called a beet harvester, then they are stored and processed to extract the sugar.

Figure 61: Sugar beet.

2.1.4. Sugar extraction

The extraction of sugar from sugar beets is done in several steps:

- ***Washing and grinding***: the beets are first washed to remove soil and debris. Then, they are ground to extract the sweet juice.
- ***Juice treatment***: the beet juice is treated to remove impurities such as fibers, proteins, and minerals. The juice is clarified using clarifying agents such as quicklime and carbon dioxide to form insoluble salts that are removed by filtration.
- ***Evaporation***: the clarified juice is then heated to evaporate the water and concentrate the sugar. This is generally done in vacuum evaporators to prevent caramelization of the sugar.
- ***Crystallization***: once the juice is sufficiently concentrated, it is cooled to allow the crystallization of the sugar. The sugar crystals are then separated from the remaining liquid (molasses) by centrifugation.

 Drying: the sugar crystals are then dried to remove residual moisture, resulting in the final crystallized sugar.

 Refining: the crystallized sugar can then be refined to remove residual impurities and improve the quality of the sugar. This may include steps such as filtration, dissolution, and recrystallization.

2.2. Oilseeds

2.2.1. Sunflower

The sunflower is an annual plant belonging to the Asteraceae family.

2.2.1.1. Biology

The sunflower can reach a height of 1 to 2 meters. Its stem is erect, hollow, with regular nodes and leaves attached to each node. The sunflower's leaves are large, rough, and green, with hairs on the upper surface. They are arranged alternately along the stem, with smaller and narrower leaves towards the top of the plant. The sunflower's flowers are bright yellow and have a flat disc shape with petals radiating from the center. They can reach a diameter of 30 cm. Sunflower flowers are composite flowers, meaning they are made up of many small flowers called florets (Fig. 62). The florets are arranged in a spiral around the center of the flower and are grouped into two types: the inner florets, which are fertile and produce seeds, and the outer florets, which are sterile and serve to attract pollinating insects such as bees. Sunflower flowers have an interesting peculiarity: they follow the course of the sun throughout the day, a phenomenon called heliotropism. Sunflower seeds are produced inside the flower heads, which are disc-shaped structures that contain hundreds of small flowers. Sunflower seeds are rich in oil and protein, and are often used for the production of cooking oil, margarine, peanut butter, and other food products.

Figure 62: Sunflower

2.2.1.2. Ecological Requirements

Sunflowers need a temperate to warm climate with average temperatures of around 20 to 25°C during the growing season. They also require well-drained and fertile soil with a pH between 6 and 7.5. Sunflowers have a high drought tolerance, making them a suitable crop for arid areas.

2.2.1.3. Technical Production Itinerary

- Sunflower cultivation begins with soil preparation, which must be well plowed and leveled.
- Seeds are generally sown in rows at a depth of 3 to 5 cm and at a distance of 45 to 60 cm between each row.
- Cultivation requires regular care such as watering, weeding, fertilization, and pest and disease control.
- Sunflower harvesting generally takes place between September and November, when the seeds have reached maximum maturity and their oil content is highest.
- The flower heads are harvested using a combine harvester, then the seeds are separated from the plant residues.

2.2.1.4. Oil Extraction

Sunflower seeds are generally cold-pressed to extract the oil. This involves using an oil press to extract the oil from the seeds without using heat or chemicals.

Sunflower oil can also be extracted using solvents such as hexane. This process is faster and more efficient, but it can leave traces of solvents in the oil.

2.2.2. Oilseed Rape

Oilseed rape is an annual plant belonging to the Brassicaceae family.

2.2.2.1. Biology

Oilseed rape is a short-cycle annual plant, which requires about 90 to 120 days to reach maturity. The leaves of oilseed rape are green, thick and serrated, and are arranged alternately along the stem. The roots of oilseed rape are taproots and can reach a depth of 1 to 1.5 meters. Oilseed rape is a self-fertile plant, which means it can reproduce with its own pollen. The flowers of oilseed rape are bright yellow and have a cross shape. They are arranged in clusters along the stem. Oilseed rape seeds are oval and black or brown in color. They are produced inside long pods, which can measure up to 20 cm in length (Fig. 63).

2.2.2.2. Ecological Requirements

Oilseed rape needs a cool to cold temperate climate with average temperatures of around 10 to 20°C during the growing season. It also requires well-drained soil rich in organic matter, with a pH between 6 and 7.5. Oilseed rape is also sensitive to water stress, which requires a sufficient amount of water to ensure optimal growth.

Figure 63: Sunflower

2.2.2.3. Technical Production Itinerary

- Oilseed rape cultivation begins with soil preparation, which must be well plowed and leveled.
- Seeds are generally sown at a depth of 1 to 2 cm and at a distance of 20 to 30 cm between each row.
- Cultivation requires regular care such as watering, weeding, fertilization, and pest and disease control.
- Oilseed rape harvesting generally takes place between June and July, when the seeds have reached maximum maturity and their oil content is highest.
- The pods are harvested using a combine harvester, then the seeds are separated from the plant residues.

2.2.2.4. Oil Extraction

Rapeseed seeds are generally cold-pressed to extract the oil. This involves using an oil press to extract the oil from the seeds without using heat or chemicals.

Rapeseed oil can also be extracted using solvents such as hexane. This process is faster and more efficient, but it can leave traces of solvents in the oil.

2.3. Aromatic Species

Aromatic plants are plants that produce essential oils or aromatic compounds that give them a characteristic odor. These plants are often used for the production of perfumes, natural flavors, essential oils, medicines and other products.

2.3.1. Tobacco

Tobacco (*Nicotiana tabacum*) is an annual herbaceous plant species in the Solanaceae family.

Tobacco is considered an aromatic plant due to its characteristic scent. Tobacco leaves contain aromatic compounds such as nicotine and terpenes that give them their particular odor. Tobacco leaves are often dried, fermented, and aged to develop their flavor and aroma. Tobacco varieties can vary in terms of taste and aroma, ranging from mild and fruity tobacco to stronger and spicier tobacco.

2.3.1.1. Biology

Tobacco roots are taproots, with lateral roots that extend horizontally in all directions. Tobacco roots are important for absorbing nutrients and water from the soil. Tobacco stems are thick and robust, with a waxy texture. They can reach a height of 1.5 to 2 meters. The stems are branched and bear alternate leaves along their entire length. Tobacco leaves are large and oval, with a heart-shaped base. They can measure up to 30 centimeters long and 20 centimeters wide. Tobacco leaves are green when young and turn yellow as they mature. The leaves are very important for tobacco production, as they contain the chemical compounds that give tobacco its aroma and flavor. Tobacco flowers are tubular, with white, pink, or red petals. They are arranged in clusters along the stems. Tobacco flowers are very fragrant and attract pollinating insects. Tobacco fruits are capsules that contain many small seeds. The capsules are spherical and measure about 1.5 centimeters in diameter. Tobacco seeds are very small and brown in color (Figure 64).

Figure 64: Tobacco

2.3.1.2. Ecological Requirements

Tobacco needs well-drained and fertile soil, with a pH between 6 and 7.5. It also requires a warm and humid climate for optimal growth. The plant is sensitive to cold and cannot tolerate temperatures below 13°C. Tobacco is generally grown in tropical and subtropical regions.

2.3.1.3. Technical Production Itinerary

Tobacco cultivation begins with the germination of seeds in well-prepared soil. The seedlings are then transplanted into a nursery before being transplanted into the field. During growth, the plant is subjected to a number of cultivation practices, including irrigation, fertilization, and pest and disease control. Harvesting takes place when the leaves have reached maturity. The leaves are then dried and fermented to develop their flavor and aroma.

2.3.1.4. Utilization

Tobacco is used primarily for the production of cigarettes, cigars, chewing tobacco, and snuff. Tobacco leaves are also used to produce tobacco oil, which is used in perfumery and aromatherapy. However, it is important to note that tobacco is a toxic plant and its use in the form of cigarettes, snuff, or chewing tobacco can have harmful effects on health.

2.3.2. Lavender

2.3.2.1. Biology

Lavender roots are taproots, with lateral roots that extend horizontally in all directions. Lavender roots are important for absorbing nutrients and water from the soil. Lavender stems are woody, thin, and branched. They can reach a height of 1 to 1.5 meters. The stems are often covered with small, narrow, linear leaves. Lavender leaves are narrow and linear, with a grayish-green color. They are arranged oppositely on the stems and measure about 2 to 6 centimeters long. Lavender leaves are very aromatic and give off a pleasant scent when rubbed. Lavender flowers are arranged in spikes at the top of the stems. They are purple, pink, or white, and are very fragrant. The spikes measure about 2 to 8 centimeters long and are composed of many small individual flowers. Lavender fruits are capsules that contain many small seeds. The capsules are ovoid and have a length of about 4 to 5 millimeters. Lavender seeds are very small and brown (Fig. 65).

Figure 65: Lavender

2.3.2.2. Ecological Requirements

Lavender needs well-drained soil, poor in nutrients, with a pH between 6.5 and 7.5. It also requires a hot and dry climate for optimal growth. The plant is drought-resistant and can tolerate temperatures down to -15°C. Lavender is generally cultivated in Mediterranean regions.

2.3.2.3. Technical Production Itinerary

Lavender cultivation begins with the planting of cuttings or seedlings in the ground. During growth, the plant is subjected to a number of cultivation practices, including irrigation, fertilization, and pruning. Harvesting takes place when the flowers have reached maturity. The flowers are then dried and distilled to produce lavender essential oil.

2.3.2.4. Utilization

Lavender is used primarily for the production of lavender essential oil, which is used in cosmetics, perfumery, and aromatherapy. Lavender flowers are also used to produce scented sachets, infusions, and massage oils. Lavender is also used in cooking to flavor desserts and drinks.

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