



**UNIVERSITY OF SZEGED
FACULTY OF AGRICULTURE**



CROP PRODUCTION

TAMÁS MONOSTORI

**HÓDMEZŐVÁSÁRHELY
2014**

CROP PRODUCTION

Written by

TAMÁS MONOSTORI

Reviewed by

ISTVÁN KRISTÓ

PÉTER JAKAB

ISBN 978-963-306-360-6

Printed in 100 copies

Published by

University of Szeged
Faculty of Agriculture
Andrássy út 15.
6800 Hódmezővásárhely
HUNGARY

INDEX

INDEX	1
PREFACE	3
1. GENERAL ASPECTS OF CROP PRODUCTION	5
1.1. CLIMATE CONDITIONS.....	5
1.1.1. Test your knowledge.....	5
1.2. SOIL CONDITIONS.....	5
1.2.1. Test your knowledge.....	8
1.3. CROP ROTATION AND CROP SEQUENCING.....	8
1.3.1. Test your knowledge.....	10
1.4. TILLAGE MANAGEMENT.....	11
1.4.1. Test your knowledge.....	14
1.5. CROP NUTRITION.....	14
1.5.1. Test your knowledge.....	17
1.6. SOWING.....	17
1.6.1. Test your knowledge.....	19
1.7. CROP CARE.....	19
1.7.1. Test your knowledge.....	20
1.8. CROP PROTECTION.....	20
1.8.1. Test your knowledge.....	21
1.9. HARVESTING.....	21
1.9.1. Test your knowledge.....	21
1.10. PRECISION FARMING.....	21
1.10.1. Test your knowledge.....	22
2. CROPS	23
2.1. CEREALS.....	25
2.1.1. Wheat.....	25
2.1.2. Rye.....	30
2.1.3. Triticale.....	32
2.1.4. Barley.....	34
2.1.5. Oat.....	38
2.1.6. Maize.....	41
2.1.7. Sorghums.....	45
2.1.8. Millets.....	48
2.1.9. Rice.....	51
2.1.10. Buckwheat and canary seed.....	54
2.1.11. Test your knowledge.....	54
2.2. PULSES.....	56
2.2.1. Pea.....	56
2.2.2. Soybean.....	60
2.2.3. Common bean.....	63
2.2.4. Lentil, chickpea, peanut, lupines and broad bean.....	66
2.2.5. Test your knowledge.....	67
2.3. ROOTS AND TUBERS.....	70
2.3.1. Potato.....	70
2.3.2. Sugar beet.....	74
2.3.3. Test your knowledge.....	79
2.4. OILSEED CROPS.....	80
2.4.1. Sunflower.....	81

2.4.2. Rapeseed (canola).....	85
2.4.3. Poppy.....	88
2.4.4. Flax grown for seed oil.....	91
2.4.5. Test your knowledge.....	91
2.5. INDUSTRIAL CROPS.....	93
2.5.1. Hemp.....	93
2.5.2. Tobacco.....	95
2.5.3. Flax grown for fibre.....	99
2.5.4. Test your knowledge.....	99
2.6. PERENNIAL FORAGE LEGUMES.....	100
2.6.1. Alfalfa or Lucerne.....	100
2.6.2. White clover.....	103
2.6.3. Birdsfoot trefoil.....	105
2.6.4. Kidney vetch.....	106
2.6.5. Sainfoin and crown vetch.....	108
2.6.6. Test your knowledge.....	108
2.7. BIENNIAL FORAGE LEGUMES.....	110
2.7.1. Red clover.....	110
2.7.2. White sweetclover.....	112
2.7.3. Test your knowledge.....	112
2.8. ANNUAL FORAGE LEGUMES.....	113
2.8.1. Egyptian clover.....	113
2.8.2. Crimson clover, fenugreek and French serradella.....	114
2.8.3. Test your knowledge.....	114
2.9. JUICY FODDER CROPS.....	116
2.9.1. Fodder beet.....	116
2.9.2. Turnip.....	117
2.9.3. Fodder kale, fodder carrot, fodder pumpkin, spring rapeseed and turnip rape.....	120
2.9.4. Test your knowledge.....	120
2.10. SUCCESSION PLANTING.....	123
2.10.1. Oilseed radish.....	123
2.10.2. White mustard.....	125
2.10.3. Phacelia.....	126
2.10.4. Test your knowledge.....	128
2.11. FORAGE MIXES.....	129
2.11.1. Winter forage mixes.....	129
2.11.2. Spring forage mixes.....	131
2.11.3. Test your knowledge.....	132
REFERENCES.....	133

PREFACE

This work deals with the production of arable crops grown under the temperate climate with special focus on those produced for feed. In the first part basic agronomical aspects such as climate and soil conditions, crop rotation, tillage management, crop nutrition, sowing, crop care and crop protection, harvesting and precision farming are discussed. In the second part basic data on the cultivation of arable crop species are given. Not all aspects are discussed in details at each species – the lacking details should be completed from the first part of the book.

Sets of questions help students to control their knowledge.

The preparation of this lecture notes was supported by TÁMOP-4.1.1.C-12/1/KONV-2012-0004.

Tamás Monostori PhD
University of Szeged Faculty of Agriculture
Institute of Plant Sciences and Environmental Protection

TÁMOP-4.1.1.C-12/1/KONV-2012-0004

Harmadik generációs összehangolt szolgáltatási portfólió és irányítási rendszer kialakítása, valamint stratégiai jellegű optimalizálás megvalósítása közösségi típusú felsőoktatási együttműködés formájában Délkelet-Magyarországon



This page is intentionally left blank.

1. GENERAL ASPECTS OF PLANT PRODUCTION

1.1. CLIMATE CONDITIONS

Among climate factors, the primary parameters influencing crop growing and development are temperature and precipitation. Minimum daily temperature for measurable growth is usually determined for species but can depend on genotype, e.g. 5 °C for wheat and 10 °C for maize. Under this value the plants do not show physiological activity. Minimum and optimum temperature for germination/emergence are characteristic values and usually exhibit a significant difference, e.g. 5 °C and 20-25 °C, respectively for wheat. Temperature regime from germination to ripening is highly genotype dependent. Highest temperature is usually needed in the last stages of ripening. In the case of crops cultivated for their vegetative storage organs (e.g. sugar beet, potato), a high difference between day and night temperatures is needed to lower the rate of dry matter losses caused by respiration. Plants have the highest water requirement in the stages of intensive growing and development, e.g. at stem elongation in small grain cereals. In the case of maize and pulses, however flowering and grain development require the highest amount of water. For some crops such as spring (malting) barley an equilibrated water supply during the growing period is necessary. Regarding water scarcity, not only soil drought but also atmospheric drought can cause severe damages in crop populations. Dry air of ca. 0% humidity stimulates transpiration of plants to extreme rates.

Daylength is important especially in the case of plants exhibiting photoperiodism. Long-day plants (e.g. spring barley, pea, lettuce) flower when the day length exceeds the critical photoperiod (ca. 12 hours), while short-day plants (e.g. rice) flower when the day lengths are less than their critical photoperiod.

Regarding climatic conditions, overwintering crops, especially winter cereals and rapeseed raise specific aspects. They require a period of exposure to low temperatures (max. 4 °C) for a given period (min. 6 weeks) to trigger reproductive development. This process is called vernalization. Furthermore, these crops are exposed to the unfavorable winter climate conditions. The lack of insulation by adequate snow cover could pose a threat to the survival of the crop. Low temperatures kill plants by injuring their crown. Suffocation occurs if ice forms on the soil surface that can cut off the oxygen supply to plants below. Puddling of water also can reduce the oxygen flow to the winter crops. In the case of heaving, freezing and thawing of the soil can lift the plants out of the ground, tearing the roots of the weak individuals.

1.1.1. Test your knowledge

List and describe the climate factors being the most important in crop production

Give the main aspects regarding temperature, water and daylength

Give the specific concerns regarding winter crops

1.2. SOIL CONDITIONS

Soils are made up of four basic components: sand, silt, clay (*Figure 1*) and organic matter. Organic Matter (OM) is made up of dead and decaying plants, animals and microorganisms. OM is a repository of nutrients that are released into the soil and it decomposes. OM also has a large water holding capacity, which helps retain moisture in soils during times of drought. Primarily organic matter is found at the top and in the uppermost layers of the soil profile, where most root growth occurs.

Sand and silt are broken down bedrock, so they usually reflect the bedrock, or parent material, found below the soil. Sand is the largest soil particle at 0.05 to 2 mm. Anything larger than that is considered to be gravel and stones. Sand, with its large diameter and low surface area to volume ratio, allows water to drain right through and does not have the ability to hold onto many nutrients.

Silt is the middle soil particle at 0.002 to 0.05 mm. Silt is commonly found in waterways and floodplains. With some water holding capacity and some nutrient holding capacity, silt is part of a good soil mix with moderate drainage and nutrients.

Clay is different from sand and silt in that it is made up of silicon, aluminum, and oxygen. It is the smallest soil particle at 0.002 mm or less and has a very high water holding capacity and a high surface area to volume ratio enabling it to be a very good nutrient holder. Soils that hold water often include a lot of clay, and many plants are specially adapted to live in high clay soils.

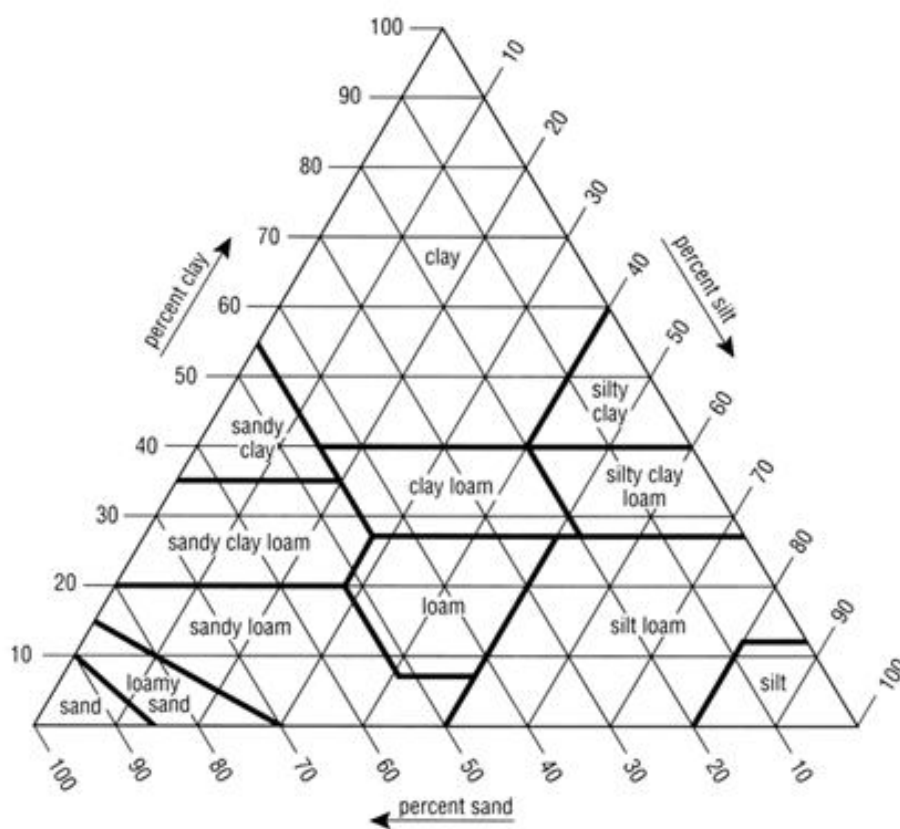


Chart showing the percentages of clay, silt, and sand in the basic textural classes.

Figure 1 Percentages of clay, silt and sand in the basic textural classes

The ideal soil is considered to be a loam, which is a mix of sand, silt and clay. Loams take advantage of the balance of water holding and nutrient availability between the three. Loamy soils with high organic matter are very well suited for high demand crops such as vegetables and fruit.

The rationalized key to the World Reference Base (WRB) Reference Soil Groups (RSGs) is shown in *Table 1*. The RSGs are allocated to sets on the basis of dominant identifiers, i.e. the soil-forming factors or processes that most clearly condition the soil formation.

The principles of the sequencing of the groups:

1. Organic soils separated from mineral soils (*Histosols*)
2. Human activity as soil-forming factor (*Anthrosols*, *Technosols*)
3. Soils with severe limitation to rooting (*Cryosols*, *Leptosols*)
4. Soils strongly affected by water (*Vertisols*, *Fluvisols*, *Solonetz*, *Solonchaks*, *Gleysols*)
5. Soils in which iron and/or aluminium chemistry plays the major role in their formation (*Andosols*, *Podzols*, *Plinthosols*, *Nitisols*, *Ferralsols*)

Table 1 Rationalized key to the WRB Reference Soil Groups

1. Soils with thick organic layers:	Histosols
2. Soils with strong human influence	
Soils with long and intensive agricultural use:	Anthrosols
Soils containing many artefacts:	Technosols
3. Soils with limited rooting due to shallow permafrost or stoniness	
Ice-affected soils:	Cryosols
Shallow or extremely gravelly soils:	Leptosols
4. Soils influenced by water	
Alternating wet-dry conditions, rich in swelling clays:	Vertisols
Floodplains, tidal marshes:	Fluvisols
Alkaline soils:	Solonetz
Salt enrichment upon evaporation:	Solonchaks
Groundwater affected soils:	Gleysols
5. Soils set by Fe/Al chemistry	
Allophanes or Al-humus complexes:	Andosols
Cheluviation and chilluviation:	Podzols
Accumulation of Fe under hydromorphic conditions:	Plinthosols
Low-activity clay, P fixation, strongly structured:	Nitisols
Dominance of kaolinite and sesquioxides:	Ferralsols
6. Soils with stagnating water	
Abrupt textural discontinuity:	Planosols
Structural or moderate textural discontinuity:	Stagnosols
7. Accumulation of organic matter, high base status	
Typically mollic:	Chernozems
Transition to drier climate:	Kastanozems
Transition to more humid climate:	Phaeozems
8. Accumulation of less soluble salts or non-saline substances	
Gypsum:	Gypsisols
Silica:	Durisols
Calcium carbonate:	Calcisols
9. Soils with a clay-enriched subsoil	
Albeluvic tonguing:	Albeluvisols
Low base status, high-activity clay:	Alisols
Low base status, low-activity clay:	Acrisols
High base status, high-activity clay:	Luvisols
High base status, low-activity clay:	Lixisols
10. Relatively young soils or soils with little or no profile development	
With an acidic dark topsoil:	Umbrisols
Sandy soils:	Arenosols
Moderately developed soils:	Cambisols
Soils with no significant profile development:	Regosols

Source: World Reference Base for Soil Resources, 2006

Land capability classification shows the suitability of soils for most kinds of field crops, excluding crops requiring special management. The soils are grouped according to their

limitations for field crops, the risk of damage if they are used for crops, and the way they respond to management.

Main features of Land Capability Classification:

- it shows the suitability of soils for most kinds of field crops
- soils are grouped according to
 - their limitations for field crops,
 - the risk of damage if they are used for crops,
 - the way they respond to management.
- criteria used in grouping the soils do not include
 - major and generally expensive landforming that would change slope, depth, or other characteristics of the soils,
 - possible but unlikely major reclamation projects
- it is not a substitute for interpretations designed to show suitability and limitations of groups of soils for rangeland, for forestland, or for engineering purposes

Capability classes of soils:

Class 1: slight limitations that restrict use.

Class 2: moderate limitations that restrict the choice of plants or require moderate conservation practices.

Class 3: severe limitations that restrict the choice of plants or require special conservation practices, or both.

Class 4: very severe limitations that restrict the choice of plants or require very careful management, or both.

Class 5: subject to little or no erosion but having other limitations, impractical to remove, that restrict use mainly to pasture, rangeland, forestland, or wildlife habitat

Class 6: severe limitations making generally unsuitable for cultivation and restrict use mainly to pasture, rangeland, forestland, or wildlife habitat.

Class 7: very severe limitations making unsuitable for cultivation and restrict use mainly to grazing, forestland, or wildlife habitat.

Class 8: limitations that preclude commercial plant production and restrict use to recreational purposes, wildlife habitat, watershed, or esthetic purposes.

Subclasses: soil groups within one class; Units: soil groups within a subclass

1.2.1. Test your knowledge

List and describe the main components of soil

Give the principles of sequencing of the Reference Soil Groups

Give the aim and features of Land Capability Classification

1.3. CROP ROTATION AND CROP SEQUENCING

Crop rotation means the successive cultivation of different crops in a specified order on the same fields. Some rotations are designed for high immediate returns, with little regard for basic resources. Others are planned for high continuing returns while protecting resources. A typical scheme selects rotation crops from three classifications: cultivated row crops (e.g. maize, potatoe), close-growing grains (e. g., oats, wheat), and sod-forming or rest crops (e.g. clover, clover-timothy). In general, cropping systems should include deep-rooting legumes. In addition to the many beneficial effects on soils and crops, well-planned crop rotations make the farm a more effective year-round enterprise by providing more

efficient handling of labour, power, and equipment, reduction in weather and market risks, and improved ability to meet livestock requirements.

Importance of crop rotation/sequencing:

- increasing soil fertility
- more efficient and versatile utilization of soil
- essential for the yield security of several crops
- soil protection
- prerequisite of planning production technologies/systems
- one of the basic tools of plant protection, weed control
- basic factor of intensive farming and economical stability
- essential in seed production (monoculture is usually forbidden)
- basis of a continuous feed supply
- tool and prerequisite of the even utilisation labourforce and machinery
- basic tool of a planned farm management
- monoculture increases environmental problems

Factors determining composition (and proportion) of crops:

- natural/environmental: e.g. climatic (temperature, precipitation, light etc.) and edafic factors (soil structure, nutrient content etc.), landscape, soil coverage,
- biological requirements and effects of crops: water and nutrient requirement, pest and pathogen control, compatibility/self incompatibility, effect of/on weed coverage, amount of root and scutbule rests
- economical/technological factors: manpower capacity, mechanization, requirements of animal husbandry

Components of crop rotation:

- crop composition (structure): the crop species grown in the whole farm or in a given part of the farm, e.g.: red clover, maize, winter wheat, spring barley
- proportion of crops: e.g. grown on fields of equal surface: I. red clover 25%, II. maize 25%, III. winter wheat 25%, IV. spring barley 25%
- sequence of crops on a given field, e.g.
 1. maize
 2. spring barley (under sown with red clover)
 3. red clover
 4. winter wheat
 It refers to all the four field parts (*Table 2*).
- rotation: the period (in years) after that each crop had been cultivated on each field and got back to the original part

Table 2 Example of a crop rotation

Year	Group of crops			
1.	I	II	III	IV
2.	III	IV	II	I
3.	II	I	IV	III
4.	IV	III	I	II

Classical (firm) rotation: permanent crop composition and proportion for a longer period
E.g.: Norfolk Four Course Rotation:

1. Turnip/Fodder beet
2. Spring barley (under sown with red clover+grass)
3. Red clover
4. Winter wheat

Flexible rotation: instead of given species, crop groups (usually plants within the same taxonomic family) of similar agronomical requirements (and characteristics/usage) are given.

E.g.:

1. row crops (instead of maize)
2. spring cereals (instead of barley)
3. forage legumes (instead of red clover)
4. winter cereals (instead of winter wheat)

Crop sequencing: cultivation of crops of different (or similar) agronomical requirements on a given field according to a planned but flexible order. Eexamples for crop sequencing are shown in *Table 3*.

Table 3 Examples of crop sequencing

Year	Annual change	Biannual change	Tri-annual change
1.	maize	maize	maize
2.	winter wheat	maize	maize
3.	winter rapeseed	winter wheat	maize
4.	winter wheat	winter wheat	winter wheat
5.	maize	winter rapeseed	winter wheat
6.	winter wheat	winter wheat	winter wheat

Monoculture: cultivation of the same crop for a longer period (years) without change on a given field

The comparison of the different cropping systems is shown in *Table 4*.

Table 4 Comparison of the cropping systems

Cropping system	Crop			
	composition	proportion	sequence	rotation
classical rotation	permanent	permanent	permanent	permanent
crop sequencing	planned	planned	variable	no
monoculture	1 species	100%	after itself	breaking

1.3.1. Test your knowledge

Describe the importance of crop rotation

Give the factors determining composition (and proportion) of crops

Describe the components of crop rotation

Compare the different cropping systems

1.4. TILLAGE MANAGEMENT

Tillage is the agricultural manipulation of the soil to prepare conditions suitable for the growing of a given crop. Tillage can also mean the land that is tilled. Based on their sequence and role, there are three types of tillage: primary, secondary and tertiary tillage.

Tillage classifications

Primary tillage: deep tillage operation (>15 cm) that loosens and fractures soil to kill weeds, reduce soil strength, mix residue, lime, fertilizers and manure into soil.

Secondary tillage: shallow tillage operation (<15 cm) to kill weeds, cut and cover residues, incorporate herbicides, prepare a pulverized seedbed.

Tertiary/cultivating tillage: in crop tillage used to control weeds or inject fertilizers and manure.

Classification of principal tillage systems

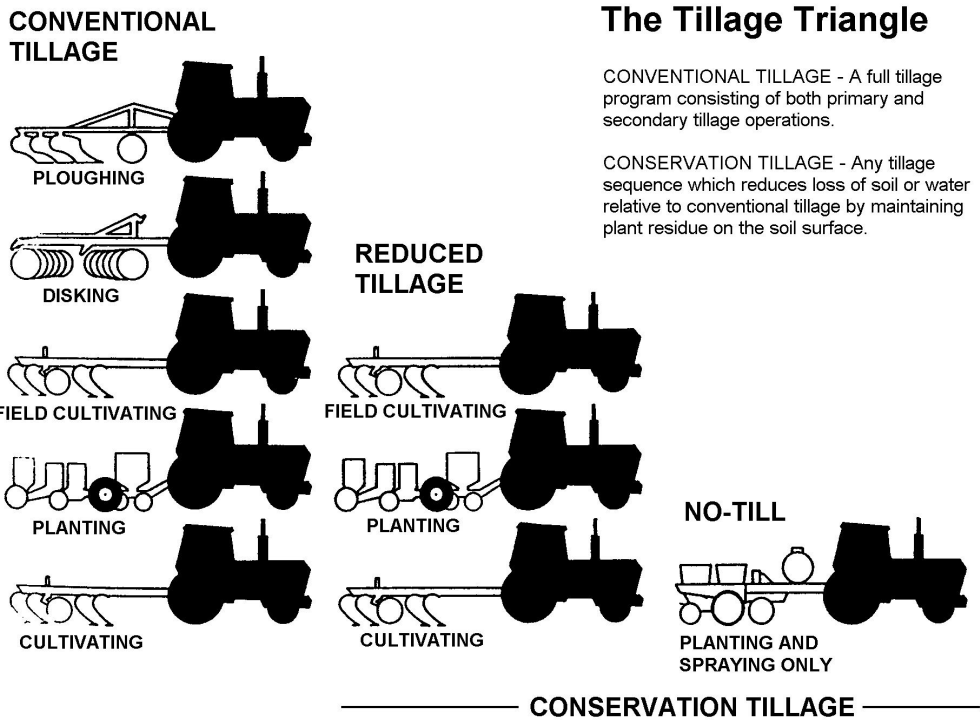
Conventional tillage involves inversion of the soil, normally with a mouldboard or a disc plough as the primary tillage operation, followed by secondary tillage with a disc harrow. The main objective of the primary tillage is weed control through burying, and the main objective of the secondary tillage is to break down the aggregates and to prepare a seedbed. Subsequent weed control may be carried out either mechanically with a cultivator, or with herbicides. The negative aspect of this system is that the soil lacks a protective residue cover and is left practically bare, meaning that it is susceptible to soil and water losses through erosive processes.

Conservation tillage is a general term which has been defined as whatever sequence of tillage operations that reduces the losses of soil and water, when compared to conventional tillage. Normally this refers to a tillage system which does not invert the soil and which retains crop residues on the surface. According to another definition, conservation tillage is any kind of tillage or sowing system which maintains at least 30% of the soil surface covered with residues after sowing so as to reduce erosion by water.

Conservation tillage includes the following systems:

- Zero tillage (direct drilling, No Till): seeds are planted into the stubble of the previous crop without any previous tillage or soil disturbance, except that being necessary to place the seed at the desired depth; weed control by the use of herbicides
- Strip tillage or zonal tillage: strips 5 to 20 cm in width are prepared to receive the seed, the soil along the intervening bands is not disturbed and remains covered with residues; more soil disturbance and less cover along the rows compared to zero tillage.
- Tined tillage or vertical tillage: the land is prepared with implements which do not invert the soil and cause little compaction; the surface remains with a good cover of residues on the surface (>30%); commonly used implements: stubble mulch chisel plough, stubble mulch cultivator, vibro-cultivator
- Ridge tillage: the system of ridges and furrows; ridges: narrow or wide, furrows: parallel to the contour lines (conserving moisture) or constructed with a slight slope (draining excess moisture.); ridges: semi-permanent or constructed each year, governing the amount of residue material remaining on the surface; semi-permanent systems: good residue cover between ridges, but still more soil disturbance and less overall cover than for the zero tillage system; the system is less conservationist than strip tillage
- Reduced tillage: the whole soil surface is tilled but one or more of the operations done with a conventional tillage system are eliminated; systems, e.g. disc harrow followed by sowing, chisel plough or cultivator followed by sowing, rotary cultivator followed by sowing

Classification of systems described above can be occasionally confusing. Reduced tillage can be conservation or non-conservation tillage system, depending on the implements used, on the number of passes, and on the amount of crop residue which remains after the seed has been placed. Thus, only land preparation with the chisel plough or tined cultivator followed by sowing could be classified as a conservation tillage system. Depending on author, minimum tillage can mean conservation tillage, zero tillage or reduced tillage, thus the usage of this term should be avoided. One way to visualize the tillage terminology is to imagine a triangle (*Figure 2*).



Source: Manual on integrated soil management and conservation practices. FAO, 2000

Figure 2 The tillage triangle

The classification of tillage systems can be based parallel on the decision between ploughing and without ploughing, as well as on the handling of stubble (*Figure 3*).

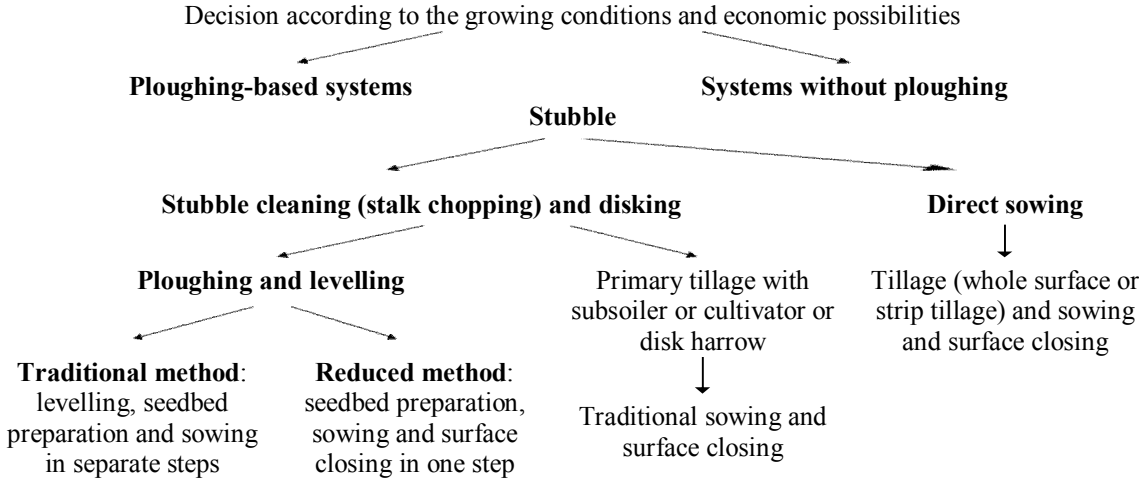


Figure 3 Main steps of the formation of tillage systems

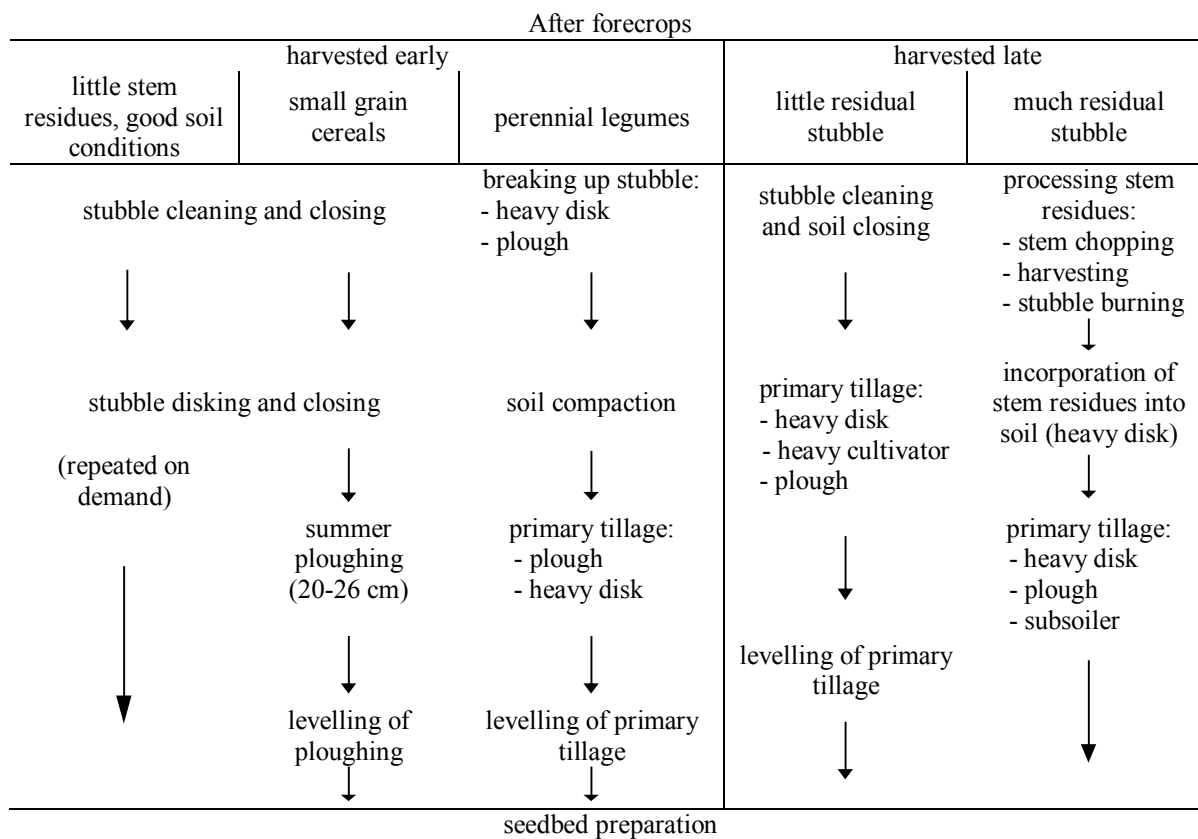


Figure 4 The tillage systems for winter crops

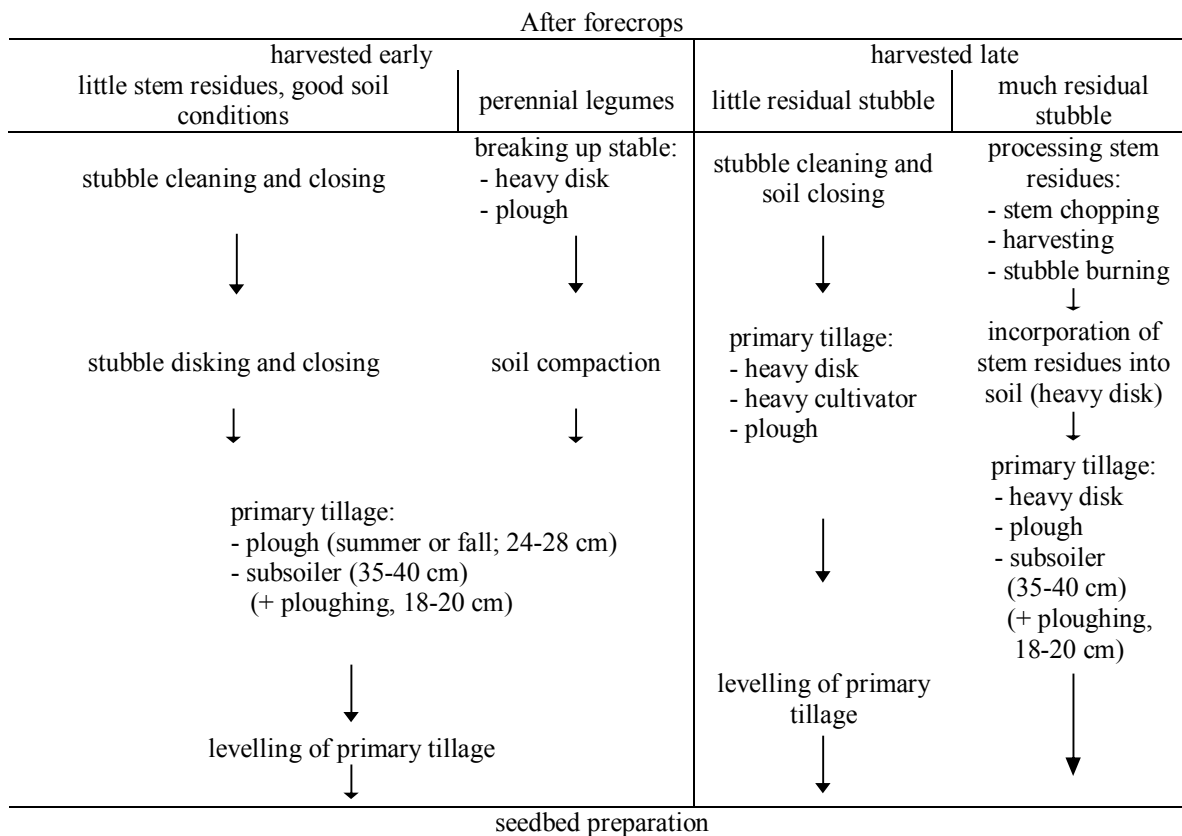


Figure 5 The tillage systems for spring crops

Tillage systems can be classified also according to the sowing time of the given crop. According to this, the two basic systems are the tillage system for winter crops (*Figure 4*) and the tillage system for spring crops (*Figure 5*).

1.4.1. Test your knowledge

Classify and describe tillage systems from different points of view

Detail the tillage system for winter/spring crops

Classify tillage methods based on the application of ploughing and handling of stubble

1.5. CROP NUTRITION

Essential plant nutrients

A total of only 16 elements are essential for the growth and full development of higher green plants according to the criteria laid down by Arnon and Stout (1939). These criteria are:

- A deficiency of an essential nutrient makes it impossible for the plant to complete the vegetative or reproductive stage of its life cycle.
- Such deficiency is specific to the element in question and can be prevented or corrected only by supplying this element.
- The element is involved directly in the nutrition of the plant quite apart from its possible effects in correcting some unfavourable microbiological or chemical condition of the soil or other culture medium.

Table 5 Essential plant nutrients, forms taken up and their typical concentration in plants

Nutrient (symbol)	Essentiality established by	Forms absorbed	Typical concentration in plant dry matter
Macronutrients			
Nitrogen (N)	de Saussure (1804)	NH ₄ ⁺ , NO ₃	1.5%
Phosphorus (P, P ₂ O ₅ ¹)	Sprenkel (1839)	H ₂ PO ₄ ⁻ , HPO ₄ ²⁻	0.1–0.4%
Potassium (K, K ₂ O ¹)	Sprenkel (1839)	K ⁺	1–5%
Sulphur (S)	Salm-Horstmann (1851)	SO ₄ ²⁻	0.1–0.4%
Calcium (Ca)	Sprenkel (1839)	Ca ²⁺	0.2–1.0%
Magnesium (Mg)	Sprenkel (1839)	Mg ²⁺	0.1–0.4%
Micronutrients			
Boron (B)	Warington (1923)	H ₃ BO ₃ , H ₂ BO ₃ ⁻	6–60 µg/g (ppm ²)
Iron (Fe)	Gris (1943)	Fe ²⁺	50–250 µg/g (ppm)
Manganese (Mn)	McHargue (1922)	Mn ²⁺	20–500 µg/g (ppm)
Copper (Cu)	Sommer, Lipman (1931)	Cu ⁺ , Cu ²⁺	5–20 µg/g (ppm)
Zinc (Zn)	Sommer, Lipman (1931)	Zn ²⁺	21–150 µg/g (ppm)
Molybdenum (Mo)	Arnon & Stout (1939)	MoO ₄ ²⁻	below 1 µg/g (ppm)
Chlorine (Cl)	Broyer <i>et al.</i> , (1954)	Cl ⁻	0.2–2 percent

Notes:

¹ Oxide forms are used in extension and trade.

² ppm = parts per million = mg/kg = µg/g; 10 000 ppm = 1 percent.

Out of these 16 elements, carbon (C) and oxygen are obtained from the gas CO₂, and hydrogen (H) is obtained from water (H₂O). These three elements are required in large quantities for the production of plant constituents such as cellulose or starch. The other 13 elements are called mineral nutrients because they are taken up in mineral (inorganic) forms. They are traditionally divided into two groups, macronutrients and micronutrients,

according to the amounts required. Regardless of the amount required, physiologically, all of them are equally important. The 13 mineral elements are taken up by plants in specific chemical forms regardless of their source (*Table 5*).

Calculation of crop nutrient requirement

The ultimate aim of all aspects of nutrient management is to: optimize crop production, maximize positive interactions, maximize net returns, minimize the depletion of soil nutrients, and minimize nutrient losses or negative impact on the environment.

The basic aspects of the effective and up to date crop nutrition practice:

- nutrition practice of various crops and its method should fit to the soils of the growing area
- plants should get an amount of nutrient that they need during the vegetation period or that we harvest with the main yield or via by-products (straw, beet-head etc.)
- uptakable nutrient content of soils should not decrease, and its increase should not reach and exceed a level being harmful for the soil, cultivation status of soil and for environment.

Basic steps of calculating nutrient supply for a given crop:

1. Determination of suitability of the soil of the growing area for the chosen crop
2. The nutrient status of the growing area (according to soil categories)
3. The N, P₂O₅ and K₂O amount taken up by 1 ton yield (together with the harvested byproduct) of the planned crop
4. Planning the possible amount of yield per ha for the given crop
5. Based on the nutrient supply data of the given growing area, calculation of the amount of N, P₂O₅ and K₂O needed for 1 ton yield
6. Considering the calculated yield, the amount of N, P₂O₅ and K₂O needed for 1 ha
7. Converting calculation of nutrients for fertilizer, manure or for their combination

General application order of fertilizers

Traditionally, it is recommended that 1/3 – 2/3 of the nitrogen, ca. 100% of phosphate (P₂O₅) and ca. 100% of potash (K₂O) be broadcasted and incorporated before planting, usually in late summer or autumn. The remaining nitrogen, phosphate, and potash are to be applied with the seed at planting (in spring). Mineral fertilizer applications should be significantly reduced when manure is also used.

Soil test results may indicate that supplemental applications of Ca and Mg are required. Limestone is an excellent source of Ca and Mg, however, if no change in pH is required, gypsum (CaSO₄) can be used for Ca and supplemental fertilizer Mg can be used.

According to the Good Agricultural Practices (GAP) related to soil, fertilizers must be applied at appropriate moments and in adequate doses (i.e., when the plant needs the fertilizer), to avoid run-off. It refers primarily to the nitrate sensitive/vulnerable zones.

Fertilizers

Nitrogen fertilization:

- application in the autumn or late summer: usually only after certain forecrops (e.g. lots of stem and root residues), max. 1/3 of the calculated dose
- for spring crops: into seed bed (can be supplemented with top-dressing, foliage-dressing)
- for winter crops: late winter - early spring (can be supplemented with top-dressing, foliage-dressing)
- fertilizer materials (N%): calcium ammonium nitrate (27%), ammonium nitrate (34%), urea (46%), anhydrous ammonia (82%), etc.

Phosphorous fertilization:

- application at primary tillage, in late summer or autumn mixed into soil (root zone)
- can also be applied as starter, at sowing
- does not move in soil
- fertilizer materials ($P_2O_5\%$): superphosphate (18-20.5%), double/triple superphosphate (36-48%), monoammonium phosphate (11% N, 52% P_2O_5), etc.

Potassium fertilization:

- application at primary tillage, in late summer or autumn mixed into soil (root zone)
- hardly moves in soil
- fertilizer materials ($K_2O\%$): potassium chloride (40 or 60%), potassium sulphate (50%), Patent Kali (30% K+10% Mg), etc.

Calcium fertilization:

- limestone is applied to neutralize the acidity in the soil and thus raise the soil pH to the optimum range for crop growth

Magnesium fertilization:

- fertilizer material: $MgSO_4$

Microelements usually controlled:

boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn), nickel (Ni)

Combined and mixed fertilizers:

- NPK in various ratios, usually liquid

Manures**Farmyard manure (FYM):**

- animal feces and plant material (straw) used in deep litter bedding
- usual doses: 30-60 tons/ha

Slurry (liquid manure):

- application according to special rules

Compost:

- decomposed remnants of organic materials (usually of plant origin)

Green manure:

- whole crops mixed or ploughed into soil as manure prior to budding or flowering stage
- beneficial effects: nitrogen/humus accumulation, reduction of mineral nutrient leaching, reduction of erosion, shadowing soil, forming granular structure of soil, reduction of the effect of intensive tillage reducing organic material content
- negative effects of wrongly chosen green manure crops: proliferation of pathogens or pests, big water consumption as well as lack of soil humidity in arid areas
- oil raddish (nematicide effect!), white mustard, fodder rape, phacelia, white lupin, white sweet clover, etc.

1.5.1. Test your knowledge

List the essential plant nutrients

Describe the steps of calculation of crop nutrient requirement

Give the general order of fertilizer application

Describe the main types of fertilizers

Describe the main types of manures

1.6. SOWING

Sowing

Placing seeds (or fruits, e.g. caryopses of grasses) of generatively propagated crops into the seed bed.

Planting

Placing vegetative parts of vegetatively propagated crops in the laid out field, e.g. potato tubers.

Transplanting

Raising seedlings on nursery beds and transplanting seedlings in the laid out field. The aim: shorten the vegetation period on the field (usually at crops demanding warm climate and/or having long vegetation period). Transplanting can also be the part of protected growing of horticultural crops (e.g. cultivating pepper, tomato, cucumber in greenhouse).

Sowing/seeding methods

Broadcast seeding

Seeds are scattered by hand or mechanically (e.g. fertilizer spreader) over a relatively large area. Seeds are incorporated by light tillage.

Application:

- by technology, e.g. alfalfa, clovers, cover crops, lawns, erosion control
- by need, in the case of unsuitable weather or soil conditions, e.g. in small grain cereals

Problem: seeds are distributed unevenly, not all the seeds are sown at the correct depth

Drilling (line sowing)

Seeds are sown into rows by a drill, at the correct depth and immediately covered. Drilling is usually followed by rolling to consolidate soil and improve germination.

Classification of drilling methods

- according to row distance:
 - tight row distance (6-8 cm), e.g. fibre crops (not common)
 - dense row distance (10.5 – 12 – 15.2 cm), e.g. small grain cereals („cereal row distance” = 12 cm), rapeseed, peas, etc.
 - broad row distance (45 – 90 cm) at row crops e.g. sugar beet (45 cm); beans, sorghum (50 cm); maize, sunflower, potato (70 – 76.2 cm); tobacco (90 cm)
- sowing with tramlines: according to the track and the wheel width of the machines, 2 x 2-3 rows are left out (the lines are usually ca. 30 cm wide and 2 metres apart while the distance between tramlines can vary from 12 metres to 30 metres)
- precision seed drilling (e.g. row crops): seeds are sown at a given plan-to-plant distance
- twin-row seeding, strip sowing: rows close together alternate with wide interrow spaces, e.g. 40 cm + 100 cm (e.g. field vegetables)

- mixed or row intercropping: two or more crops sown at the same time (e.g. fodder mixes); regular mixing in the hopper during seeding process is necessary to prevent fractionation
- strip (inter)cropping: crops of dense and broad row distance sown intermittently (soil protection e.g. on slopes)
- top-/overseeding: at thin crop populations (e.g. alfalfa stands) or mix populations (e.g. winter cereals overseeded with spring legumes)
- inter-row sowing: (1) a crop of short growing period cultivated between the rows of a row-crop (can be considered as a type of row intercropping, e.g. bean or squash sown between maize rows); (2) seeding on the previous year's inter-row (to improve handling of heavy stubble loads, to avoid soil-borne diseases in cereals, to offer protection against wind and rain, to reduce tillage and promote soil health, etc.)

Parameters of sowing

Sowing time:

- autumn: e.g. winter cereals
- early spring: e.g. spring cereals, peas, lentil, poppy, alfalfa, early potato, sugar beet
- mid-late spring: e.g. sunflower, maize, sorghum, beans
- early summer: e.g. green bean, secondary crops
- late summer: e.g. alfalfa, rapeseed

Sowing depth:

- shallow -deep: wet – dry soil, compact – loose soil, small – big seed size, epigeic - hypogeic germination

Seeding rate depends on:

- crop species/variety
- aim of production
- sowing method and quality
- climate and weather
- quality and nutrient content of seed bed
- sowing time
- Pure Live Seed (PLS) value

Calculation of seeding rate

Plant density is known

$$\text{Seeding rate (kg/ha)} = \frac{\text{plant density (seed/ha)} \times \text{thousand grain weight (g)}}{1,000,000}$$

$$\text{Pure Live Seed (PLS)} = \frac{\text{percent (\%)} \text{ purity} \times \text{percent (\%)} \text{ total germination}}{100}$$

$$\text{Corrected seeding rate (kg/ha)} = \frac{\text{seeding rate (kg/ha)} \times 100}{\text{PLS}}$$

Simplified, combined formula:

$$\text{Seeding rate (kg/ha)} = \frac{\text{plant density (seed/ha)} \times \text{thousand grain weight (g)}}{\text{percent (\%)} \text{ total germination} \times \text{percent (\%)} \text{ purity} \times 100}$$

Seed number per running meter is known

$$\text{Running meter per hectare (rm/ha)} = \frac{\text{ha (m}^2\text{)}}{\text{row distance (m)}}$$

Plant density (seed/ha) = running meter (rm) x plant density (seed/rm)

$$\text{Seeding rate (kg/ha)} = \frac{\text{plant density (seed/ha)} \times \text{thousand grain weight (g)}}{\text{percent (\%)} \text{ total germination} \times \text{percent (\%)} \text{ purity} \times 100}$$

Plant-to-plant distance is known

$$\text{Running meter per hectare (rm/ha)} = \frac{\text{ha (m}^2\text{)}}{\text{row distance (m)}}$$

$$\text{Plant density (seed/ha)} = \frac{\text{rm/ha}}{\text{plant-to-plant distance (m)}}$$

$$\text{Seeding rate (kg/ha)} = \frac{\text{plant density (seed/ha)} \times \text{thousand grain weight (g)}}{\text{percent (\%)} \text{ total germination} \times \text{percent (\%)} \text{ purity} \times 100}$$

1.6.1. Test your knowledge

Describe the sowing methods

Give the parameters of sowing

Calculate seeding rate if seed density, seed number per running meter or plant-to-plant distance is known

1.7. CROP CARE

Techniques applied on the field or on the plants after sowing, prior to harvesting.

Mechanical care

Methods usually using tillage implements:

- in-crop tillage (inter-row cultivation): mechanical weed control, shattering compacted surface/subsurface layers, loosening soil, etc.
- ridge or furrow forming (e.g. potato, ground-nut)

- rolling winter crop fields at the end of winter: preventing negative effects of freeze-thaw cycles (freezing and heaving) of soils
- setting plant density (in row crops)
- in tobacco: inflorescence removal, axillary bud control
- in seed production: roguing
- in seed corn: removing secondary tillers, detasselling

Irrigation

Artificial application of water on the field.

Main types of irrigation:

- surface/flood; sprinkler, center pivot, lateral kove/wheel line (primarily on the field, also in greenhouse), drip irrigation (primarily in protected growing, also on the field)
- main point of view: many times, smaller doses - better misting effect (in the case of sprinkler)
- average dose: 40-50 mm
- advantages:
 - sprinkler: increasing air humidity
 - drip irrigation: sparing water, application of fertilizer possible

1.7.1. Test your knowledge

Describe the most important techniques of crop care

Describe the irrigation methods

1.8. CROP PROTECTION

Classification of pests:

- weeds (mono- and dicots, various life forms)
- pathogens (fungi, bacteria, viruses, etc.)
- pests (insects, other arthropods, molluscs, birds, mammals, etc.)

Basic protection strategies:

- weed control: crop sequencing, mechanical, (presowing), preemergent, postemergent chemical weed control (herbicide tolerant GM varieties as well)
- weeds can be classified according to their life forms (Raunkiaer, Ujvárosi):
 - Annuals: Therophytes (T): T1, T2 - winter annuals (weeds of cereals); T3, T4 – summer annuals (weeds of root crops)
 - Biennials: Hemitherophytes (HT)
 - Perennials: Geophytes (G: G₁-G₄), Hemicryptophytes (H: H₁-H₅), Phanerophytes (Ph), Chamaephytes (Ch)
- seed coating: fungicide and/or insecticide
- against pathogens: crop sequencing, resistant/tolerant varieties, fungicides, bactericides
- against pests: quarantine, crop sequencing, soil disinfection, insecticides, GM (Bt-toxin producing) varieties
- biological crop protection:
 - against pathogens: hyperparasite and antagonist microorganisms
 - against pests: pheromone traps, „self-limiting” method/Sterile Insect Technique (SIT: distribution of sterile males), living organisms, (natural) enemies (usually predator insects, parasites)

1.8.1. Test your knowledge

List the crop pests

Describe the basic crop protection strategies

1.9. HARVESTING

Timing

Timing of harvesting is determined by the utilization of the crop, and it is normally set to a certain stage of development:

- usually in full ripening: e.g. at small-grain cereals (<16% seed moisture content)
- dough stage: forage maize (ca. 40% seed moisture)
- at given degree of firmness determined by finometer/tenderometer (green pea)
- in technical maturity (prior to biological maturity, e.g. hemp, occasionally sugar beet)
- after desiccation/growth regulation: e.g. rapeseed, sunflower

Implement:

- usually combine (harvester-thresher) equipped with special adapter
- special harvesters, e.g. sugar beet, potato, green pea
- forage harvester (chopper), e.g. silage maize

1.9.1. Test your knowledge

Give examples for timing and implements of harvesting

1.10. PRECISION FARMING

Precision farming or precision agriculture is an agricultural concept relying on the existence of in-field variability. It requires the use of new technologies, such as global positioning (GPS), sensors, satellites or aerial images, and information management tools (GIS) to assess and understand variations. Collected information may be used to more precisely evaluate optimum sowing density, estimate fertilizers and other inputs needs, and to more accurately predict crop yields. It seeks to avoid applying inflexible practices to a crop, regardless of local soil/climate conditions, and may help to better assess local situations of disease or lodging.

Aspects of soil science and agricultural chemistry

Application of Global Position System (GPS) helps:

- to treat earlier information about the given field (e.g. yield map, soil map, area damaged by pathogens, pests and weeds, the rate of damage) in a uniform system and to perform treatments (fertilization, plant protection etc.) in a site-specific manner.

Basic elements of a positioning-based production:

- yield map: it shows the common effect of many, in lots of cases independent factors (e.g. effects of diseases, pests, weeds, technological failures)

Essential:

- preparation of field maps, building a GIS-based geoinformational system, division of the field into homogenous parts of easy-to-handle size
- the patches can be identified by GPS, equipments mounted on the machines can recognize them, the doses can be changed and set for the current, local conditions.

Aspects of water management

Water is (and will be) one of the determining factors in the development of agriculture and environmental protection. Thus, to increase the efficiency of water usage, the regulation of water regime of soils is an exceptional key task.

Due to the restricted possibilities of the regulation of the water management in the soil (irrigation, drainage) – one of the most progressive solutions is the site-specific regulation of soil moisture content in the frame of precision farming.

Basic factors of the water regime of soil are the structure of the soil section, succession and thickness of layers between soil surface and the level of ground water (water table), moisture content, chemical composition of soil moisture, its vertical and horizontal movement etc. To make a scientifically reliable interference possible, exact and quantitative data about these factors, and about the evaluation of their probability and frequency are required.

Aspects of plant production

Almost all components of production technology can be related with precision solutions:

- Tillage (according to the forecrop, to the structure and status of soil and to its suitability for cultivation)
- Nutrient supply (depending on the nutrient status of the given soil point, and on the current state of development of the plant population)
- Water supply (according to the correspondence between water supplying ability of soil and water requirement of the crop)
- Sowing (site- and species/variety-specific plant density, row distance, sowing depth)
- Crop care (technological interventions based on field status surveys)
- Plant protection (development of methods of integrated prophylactic and symptomatic treatments applied against pests, pathogens and weeds)
- Harvesting (adaptation to inhomogenities in the ripening conditions)

Aspects of plant protection

One of the big contradictions of the conventional plant protection practice is that the distribution of pests on the field is inhomogenous while treatments are planned and performed in a homogenous way. The negative consequence of this contradiction is the pesticide input in excess which is not desired neither from economical nor from environmental protectional point of view.

The two main fields of plant protection where techniques of precision farming can be involved:

- Determination of temporal and spatial details of preventive protection methods. It has the primary importance in protection against pathogens and animal pest as well as in preemergent weed control.
- Postemergent weed control and decision making based on the characterization of symptoms to prevent the escalation of an epidemics in the presence of the pest

These two main directions of development require different solutions. In the first case, traditional equipments and theoretical models stay in use by pest forecasting but data are processed by computer based simulation models and algorithms. In the second case, the newest developments of precision farming should be applied.

1.10.1. Test your knowledge

Give the general considering of precision farming

Describe the main aspects of soil science and agricultural chemistry/water management/plant protection in precision farming

2. CROPS

The harvested area and yield of some important arable crop species is shown in *Table 6*.

Table 6 Harvested area and yield of some important crop species in the World (FAO, 2012)

Crop species	Area harvested (ha)	Yield (tons/ha)
Cereals		
Wheat	215,489,485.42	3.11
Rye	5,564,996.30	2.62
Triticale	3,691,578.00	3.70
Barley	49,525,988.25	2.69
Oats	9,608,318.00	2.19
Rice, paddy	163,199,090.36	4.41
Maize	177,379,506.63	4.92
Maize, green	1,125,915.64	8.67
Sorghum	38,161,647.00	1.49
Millet	31,757,583.00	0.94
Canary seed	217,799.00	0.88
Buckwheat	2,525,124.00	0.90
Pulses		
Soybeans	104,997,252.85	2.30
Peas, dry	6,593,926.47a	1.49
Peas, green	2,266,368.61	8.16
Beans, dry	29,290,861.00	0.81
Beans, green	1,535,387.56	13.51
Lentils	4,206,024.00	1.08
Chick peas	12,344,291.00	0.94
Cow peas, dry	11,294,193.00	0.51
Lupins	887,014.00	1.45
Pigeon peas	5,324,322.00	0.79
Groundnuts, with shell	24,709,457.90	1.67
Roots and tubers		
Potatoes	19,202,081.65	18.99
Sugar beet	4,900,845.40	55.07
Oilseed crops		
Sunflower seed	24,843,104.00	1.51
Rapeseed	34,085,066.00	1.91
Linseed	2,485,810.00	0.83
Poppy seed	70,406.00	0.63
Industrial crops		
Hemp tow waste	41,246.00	1.29
Flax fibre and tow	218,919.00	1.11
Hops	76,951.00	1.51
Tobacco, unmanufactured	4,291,014.26	1.75
Forage legumes		
Vetches	651,987.00	1.46

Features of primary crops according to FAO:

- Primary crops are directly from the land, without having undergone any real processing, apart from cleaning;
- All the biological qualities they had still on the plants are maintained;
- Certain primary crops can be aggregated, according to e.g. their yield, production or utilization, such as cereals, roots and tubers, nuts, vegetables and fruits.
- Other primary crops can be aggregated in terms of one or other component common to all of them, e.g. oilseed crops aggregated in terms of oil or oil cake equivalent
- Primary crops are divided into two groups:
 - Temporary crops are sown and harvested during the same agricultural year, sometimes more than once
 - Permanent crops: sown or planted once and not replanted after each annual harvest

2.1. CEREALS

Common feature of cereals is the seed (kernel) of high starch (flour) content. Most of them belong to Gramineae.

2.1.1. Wheat (*Triticum aestivum* L.)

Wheat is the largest arable crop in the world regarding its growing area (215,489,485 ha). Its global production is 670,875,110 tons (FAO, 2012).

Wheat can be utilized several ways for food (e.g. flour, semolina, groats, bread, pastas, doughs, biscuits, vital glutene, flakes, bran), feed (e.g. grain, forage, forage-mixes: wheat and Pannon vetch mix, wheat and autumn pea, Legány-mix). Its by-product is straw that can be used as litter as well as for energy and bio-fuel production.

100 g of hard red winter wheat contains about 12.6 g of protein, 1.5 g of total fat, 71 g of carbohydrate, 12.2 g of dietary fiber, and 3.2 mg of iron. Compared to other cereals, it contains higher levels of P, Zn, Cu, Mn, Se, vitamin B₃, vitamin E

Wheat varieties can be classified in terms of: growing season (winter wheat or spring wheat), maturity (early, medium, medium-late, late), ecotype (wheat of humid climate, steppe-type, desert or semi-desert type, uplands), seed color and seed hardness (hard red winter wheat, soft red winter wheat, hard red spring wheat, white wheat).



Figure 6 Wheat: awnless (left) and awned (centre) genotype, demonstration plot (right)

Botanical characteristics

Wheat and other small grain cereals has two types of roots, the seminal roots (one primary root and 4-6 lateral seminal roots) and the nodal roots (adventitious or crown roots), which arise from the lower nodes of the shoot. Shoots (straw) are made up of internodes (6-16/shoot) separated by nodes. Straw is usually hollow but it can also be thick-walled and solid. Wheat plants are usually 90-100 cm tall depending on genotype. Tillers having the same basic structure as the main shoot, arise from the axils of the basal leaves. A leaf is inserted at each node of the stem, the uppermost leaf being called flag leaf. Leaves have three parts: leaf sheath, leaf blade and ligule. Auricles are appendages at the base of the leaf blade. Their size is characteristic for the species - in the order of decreasing size: barley, wheat (often hairy), rye, oat (no auricle). Leaves, stem and inflorescence can possess a coat of wax depending on variety and environment. The inflorescence of wheat is a spike (ear or head) composed of ca. 20 spikelets that are alternately arranged on the rachis. Spikelets have two glumes that enclose two to eight florets (usually up to 5 fertile).

The outer parts of each floret consist of a lemma and a palea. The floret is composed of two lodicules, three stamens with anthers, ovary with a hairy stigma of two arms. According to awnedness (awns are on lemmas) awnless, apically awnletted, awnletted and awned spikes can be distinguished (*Figure 6*). The spike shape can be tapering, oblong, clavate or fusiform. Spike attitudes at maturity range erect (upright to 30°), semi-erect, inclined (30° to 90°), horizontal, semi-nodding and nodding (>90°). The grain (kernel or caryopsis) is a complete fruit developing from one floret. It has a pericarp of the fruit fused with the seed coat, typical of the grasses, and the entire kernel is can be referred to as the seed. It is usually oval but it can range from almost spherical to long, narrow and flattened. Its color is red (brownish) or white (yellowish). Kernels of small grain cereals have a crease on the ventral side, hairy structures (brush) on the distal end and the germ on the lower end. Kernels are coated by several layers of tissues (the bran): epidermis, hypodermis, cross cells, tube cells, seed coat, nuclear tissue (hyaluron), aleurone cells. Aleurone cells build the outer layer of endosperm and contain enzymes (hydrolases) that take part in the decomposition of storage nutrient during germination. Endosperm fills out the center of the grain. Its cells contain granules of starch surrounded by a clear glassy protein. Thousand kernel weight of wheat is 40-44 g.

Its centers of origin are the Fertile Crescent and Southwest Asia, as well as the Caucasus, Afghanistan, Iran and Asia Minor. *Triticum* spp. belong to the family Gramineae/Poaceae. *T. aestivum* is an amphidiploid/allohexaploid (AABBDD, 2n=42) of *T. urartu/boeoticum* (AA, 2n=14), (supposed) *T. speltoides/searsii* (BB, 2n=14) and *Aegilops squarrosa* (syn, *T. tauschii*; DD, 2n=14). *T. spelta* is also allohexaploid, *T. durum* and *T. dicoccum* are tetraploid lacking the D-genome. *T. monococcum* is diploid (2n=14), containing the A-genome.

According to the extended BBCH-scale, wheat and other small grain cereals have the following principal phenological growth stages:

- 0: Germination
- 1: Leaf development
- 2: Tillering
- 3: Stem elongation
- 4: Booting
- 5: Inflorescence emergence, heading
- 6: Flowering, anthesis
- 7: Development of fruit
- 8: Ripening
- 9: Senescence

Winter wheat usually starts tillering in the autumn and continues in the spring. Winter wheats require a period of exposure to low temperatures (max. 4 °C) for a given period (min. 6 weeks) to trigger its reproductive development. This process is called vernalization. Flowering of spikes (anther visible on the spike surface) starts in the middle flowers and extends towards the ends. Wheat is self-pollinated, cross pollination can occur depending on genotype and/or climate up to 10%.

Environmental requirements

Wheat is cultivated worldwide from subarctic to tropical areas and up to above 1500 m of altitudes. The growing period ranges from 180 to 280 days for winter wheat and from 100 to 130 days for spring wheat. Minimum daily temperature for measurable growth is about 5 °C, however germination starts at ca. 3-4 °C (optimum: 18-25 °C). Winter wheat in its early developmental stages is resistant to frost down to -20 °C. This resistance is lost in the

active growth period in spring. Frost during head development and flowering periods can cause head sterility. Mean daily temperature for optimum growth is 15-20 °C. Extreme high temperature and drought in the early stages of fruit development can lead to forced ripening, incomplete grain filling and to the formation of poor quality shrivelled grains of low 1000 kernel weight. For last stages of ripening a dry, warm period of 18 °C or more is preferred. Precipitation in this period causes delayed harvesting and decrease in quality (e.g. low falling number). Wheat grown under temperate climate requires 450-650 mm precipitation in the growing period. Growth stages of highest water requirement are stem elongation, grain filling and germination.

Wheat can be grown on a wide range of soils. Most preferred are soils of deep fertile surface layer (tilth) that are rich in nutrients, exhibit a good water supply and have a medium texture. The optimum pH ranges from 6 to 8. Soils of shallow surface layer, eroded soils, loose sand, extreme hard soils and peaty soils should be avoided. Wheat is relatively tolerant to a high groundwater table.

Cultivation

Wheat, especially winter wheat, has special requirements regarding forecrops. It prefers early harvested forecrops that does not exploit water and nutrient content of soil and leave it in good condition without weeds. Best forecrops are pulses (except for soybean), legumes, winter and spring forage mixes, rapeseed, flax, hemp, tobacco, early potato, sweet corn, field vegetables, herbs, etc. Forecrops of medium quality are early grain corn, sunflower, sugar beet, small grain cereals, etc. Forecrops harvested late (after the end of September) such as corn, sunflower and especially sorghums, should be possibly avoided, especially for winter wheat. Wheat can be sown after wheat maximum once.

Table 7 Nutrient requirement of wheat

Nutrient uptake to 1 ton of grain				
N: 27 kg/t	P ₂ O ₅ : 11 kg/t	K ₂ O: 18 kg/t	CaO: 6 kg/t	MgO: 2 kg/t

Table 8 Sowing data of wheat

Sowing date: - winter wheat - spring wheat	5-20. October 25. February - 20. March
Row distance:	10.16 or 12 or 15.24 cm (in several countries: 25 - 30 cm)
Sowing depth:	4-6 cm
Seed rate: - good tillering, extensive genotypes - less tillering, intensive genotypes or unfavourable conditions	5 - 5.5 million seeds/ha 5.5 - 6 million seeds/ha (ca. 3 million seeds/ha for hybrid wheats or broader row distances) (130) 200-250 kg/ha
1000 seed weight:	40-44 g

Following stubble cleaning and discing, soil cultivation allows for 22-25 cm deep tillage using a cultivator or disk, and then closing the soil surface within 24 hours with a rolling

harrow or ground roll with grain residues. After forecrops leaving high amounts of stem residues, stem chopping is the first step. This case, tillage method requires 22-25 cm deep ploughing closed with a rolling harrow or ground roll. Seedbed is usually prepared by a combinatory.

Basic fertilization and sowing data can be found in *Tables 7* and *8*, respectively. In general, the effective ingredient dose is 200-260 kg/ha NPK (2:1:1). In given conditions, for good yields up to 150 kg/ha N, 35 to 45 kg/ha P and 25 to 50 kg/ha K are recommended. In several countries small grain cereals are advised to be sown in winter at 18 cm and 10 cm in spring. Row distances of 25 and 36 cm are also applied in a number of countries. Target plant population is usually lower (3.5-4.5 million/ha for winter, 3.0-4.0 million/ha for spring wheat). In the UK, optimum plant population of as low as 600,000-1,600,000 plants/ha has been determined, depending on sowing date. Based on the amazing capacity of wheat to produce tillers, declined shoot number does not result in decreased yield due to the larger individual shoots (larger green area), larger spikes (more grains per ear) and larger grains (increased 1000 grain weight).

In winter wheat the braking of ice layer by a tractor or roller, the rolling of fields at the end of winter to prevent negative effects of freeze-thaw cycles of soils, the drainage of fields to overcome inundation (and waterlogging) may be necessary. The application of plant growth regulators, usually at the end of tillering, shortens stem height, increases stem thickness thus preventing lodging and increasing yield potential. However, application of regulators is relatively expensive and it belongs to the intensive technologies usually in seed production.

Diseases

Leaf rust (*Puccinia recondita* f. ssp. *tritici*), stem rust (*P. graminis* f. ssp. *tritici*), yellow rust (*P. striiformis*), powdery mildew (*Erysiphe/Blumeria graminis* f. ssp. *tritici*), head blight (*Fusarium graminearum*), yellow leaf spot (*Drechslera/Pyrenophora tritici-repentis*), loose smut (*Ustilago tritici*), common bunt (*Tilletia foetida*), barley yellow dwarf virus (BYDV)

Pests

Cereal leaf beetle (*Oulema melanopus*), cereal ground beetle (*Zabrus tenebrioides*), Hessian fly (*Mayetiola destructor*), green bug (*Schizaphis graminum*), wheat bugs (*Eurygaster maura*, *E. austriaca*, *Aelia acuminata*, *A. rostrata*), wheat grain beetle (*Anisoplia austriaca*), wireworms (*Aeolus* sp., *Anchastus* spp., *Melanotus* spp., *Limonius* spp.), armyworms, cutworms, mites

Harvesting

Wheat is harvested by a combine in fully ripe stage at moisture content below 16%. Grain loss must be below 4%. Delayed harvesting in over-ripe stage increases grain-loss and decreases quality. Wheat can be stored at a maximum of 14-14.5% water content. Its average yield is 5-6 (up to 8) tons/ha.

Wheat quality parameters

Hectoliter weight The weight of 100 l grains in kg. Its value is ca. 76-80 kg.

Grain hardness (endosperm texture) Resistance of wheat grain against deformation. Soft-grained: index < 50; hard-grained: index > 50.

Protein content Wheat crude protein content is 12-15%.

Gluten content Gluten is the water-insoluble fraction of wheat grain protein, the composite of a gliadin and a glutenin. Gluten gives elasticity to dough. Wet gluten content is between 25 and 40%.

Farinogram Farinograph absorption is the amount of water that must be added to flour to give the required consistency (%). The graph represents the digital output of a strain gauge that measures resistance during mixing, used to indicate the mixing properties of dough. It is reported as a percentage (*Figure 7*).

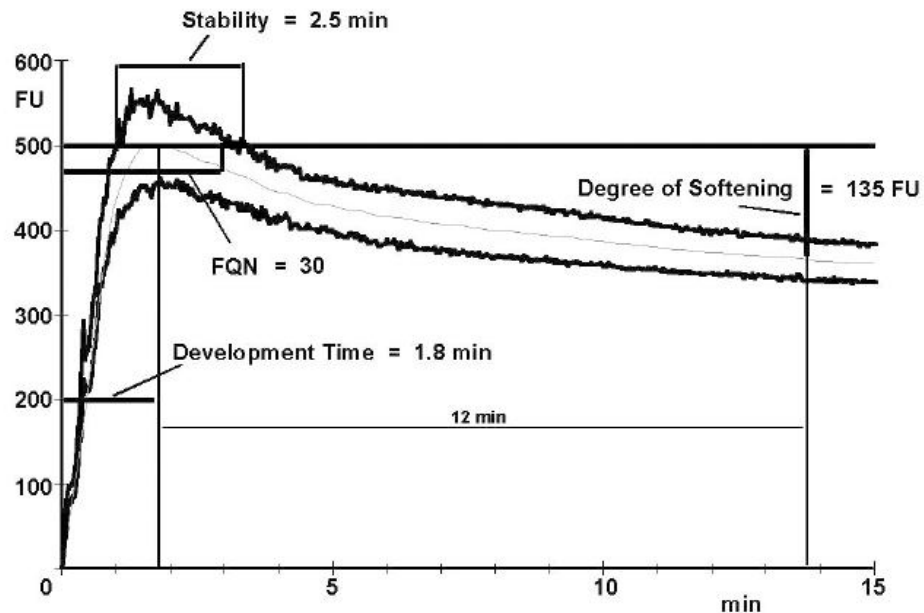


Figure 7 Farinogram

Falling number It exhibits enzyme (primarily α -amylase) activity of flour. Optimum value: >250 sec.

Alveogram W-value shows the common effect of stability and extensibility. Excellent: $W > 250$; good: $W > 160$. P/L is the proportion of stability and extensibility (*Figure 8*).

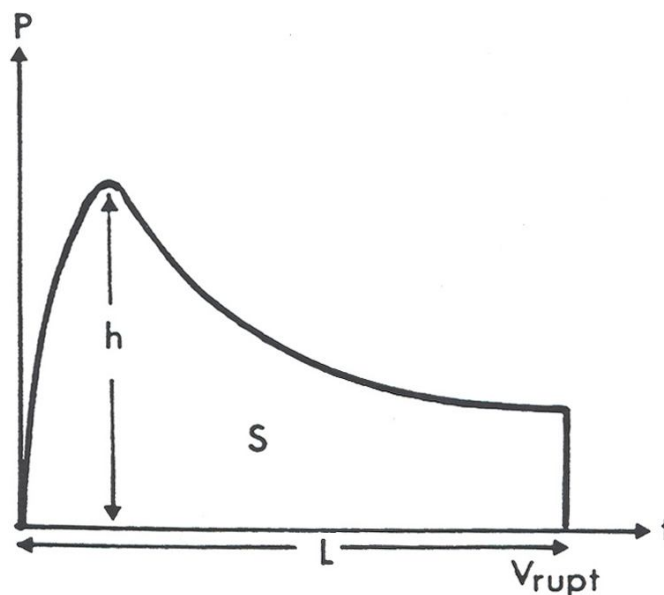


Figure 8 Alveogram

Extensogram R_{max} : maximum resistance, E : extensibility, A : the area under the curve, the common effect of stability and extensibility; weak < medium: $50-80 \text{ cm}^2$ < strong (Figure 9).

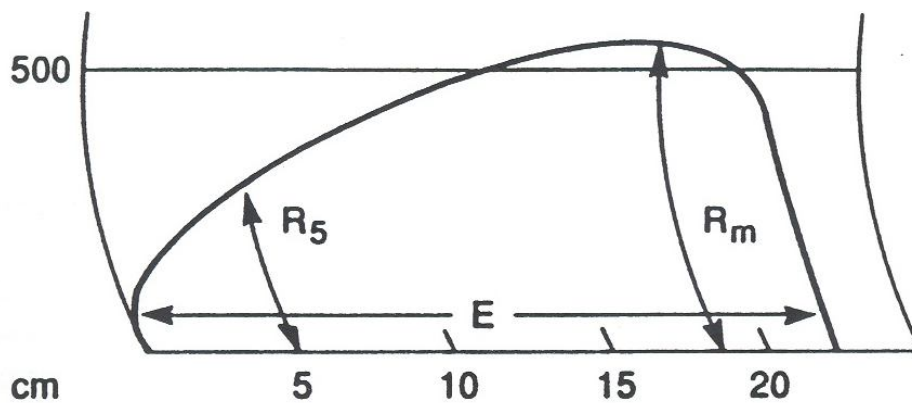


Figure 9 Extensogram

Sedimentation value (Zeleny number) Complex value of quantity, quality and utility of wheat gluten; optimum: 30-35 ml.

2.1.2. Rye (*Secale cereale* L.)

Rye has a slowly decreasing growing area of 5,564,996 ha in the world with a global production of 14,562,055 tons (FAO, 2012).

Rye is grown as a grain, as a forage crop as well as a cover and green manure crop. For human consumption purposes rye grain is used for flour, rye bread, rye beer, crisp bread, whiskey, vodka. As animal feed it is utilized as grain forage or pasture.

Rye has a beneficial physiological effect and composition. It has a high dietary fibre and ash content. The high percentage of complex carbohydrates is digested more slowly than simple carbohydrates, and they are less likely to be converted to fat. It has a relatively high Mg, K, vitamin B₁ and vitamin B₂ content. It has a lower protein content compared to wheat but a more favorable amino acid composition (e.g. high lysine content).

Botanical characteristics

Basic characteristics are the same as mentioned at wheat. Its root system is stronger with more nodal roots and reaches a bigger depth. It is the basis of the excellent adaptability of traditional (tall) rye cultivars. Intensive genotypes of shorter stem have a less extended root system and lower capability for adaptation. Traditional cultivars are tall, up to 2 m or more. Stem and leaves of mature plants exhibit a typical bluish, blue-greyish color (Figure 10). Purple or red color occurring mainly on nodules and awns is caused by anthocyanins and can be characteristic for given genotypes. The inflorescence is a usually lax, slender, 10-15 cm long spike. The spikelets contain three florets, with the two outer florets being fertile. Like in wheat, the lemma and palea enclosing the floret are free-threshing. Glumes are narrow and open, the lemmas being longer than glumes, taper gradually and often bear barbs on the keel and awns. The kernels are longer and more slender than those of wheat. They have a typical greenish grey color due to lack of complete decomposition of chlorophyll during ripening. The 1000 kernel weight is 30-35 g.



Figure 10 Rye

Rye starts intensive tillering early and it is finished mainly in autumn. Rye is largely cross-pollinated, as most rye plants are self-sterile, and characteristically some florets fail to set seed. Rye seeds are still physiologically active at harvesting, they lack dormancy. Its center of origin is Southwest Asia (same as for wheat). Annual wild rye (*S. silvestre*) originates from perennial Anatolian mountain rye (*S. monatum*). Wild rye was spread as the weed of wheat. It spontaneously crossed with other rye species leading to the generation of cultivated rye. Rye belongs to the family Gramineae/Poaceae. *S. cereale* is diploid ($2n=14$), containing the R-genome. Besides varieties, hybrid rye is also grown extensively.

Environmental requirements

Rye prefers cool and humid climate but it has an extreme adaptability. It tolerates drought, cold winter and long snow cover. The growing period ranges from 260 to 280 days. Its germination starts at just above 0 °C (optimum: 18-25 °C). For its quick development a mild and rainy autumn and a long, cool spring is preferred. A humid May and a cool June is beneficial for perfect development of grains. Late-spring frost, cold and stormy weather during flowering result in fertilization defects, in partially fertilized spikes. Growth stages of highest water requirement are stem elongation, grain filling and germination.

Rye grows well in much poorer soils compared to other small grain cereals. It is an especially valuable crop in regions where the soil contains sand or peat. On soils of better quality (especially higher humus content) wheat and other cereals give better yield, furthermore rye becomes more susceptible to lodging.

Table 9 Nutrient requirement of rye

Nutrient uptake to 1 ton of grain				
N: 25 kg/t	P ₂ O ₅ : 12 kg/t	K ₂ O: 26 kg/t	CaO: 8 kg/t	MgO: 2 kg/t

Cultivation

Rye does not have special requirements regarding forecrops. It can be grown even in monoculture for several years but rotation is an effective method of prevention against several pests. Best forecrops are all those harvested early, e.g. potato, yellow lupin (on acidic sand), sweet clover (on alkaline sand), tobacco, oilseed radish. In the course of soil

preparation, the compaction of seed bed before and after sowing is essential to avoid getting seed too deep in loose soils (e.g. sand). Basic fertilization and sowing data can be found in *Tables 9* and *10*, respectively. In general, the effective ingredient doses are 60-70 kg/ha N, 35-45 kg/ha P and 45-55 kg/ha K.

Table 10 Sowing data of rye

Sowing date:	20 - 30. September
Row distance:	10.16 or 12 or 15.24 cm
Sowing depth.	4-6 cm
Seed rate:	4.5 - 5 million seeds/ha 160 - 180 kg/ha
1000 seed weight:	30-35 g

Diseases and pest

Rye suppresses weeds effectively due to its rapid development. Diseases and pest are basically the same listed for wheat. Rye is, however, highly susceptible to the ergot (*Claviceps purpurea*).

Harvesting

Rye is harvested by a combine in fully ripe stage at moisture content below 16%. Grain loss must be below 4%. Rye lacks dormancy thus preharvest sprouting can happen under humid ripening period. Due to long enzyme activity, rye grains must be regularly mixed and aerated during storage to control temperature to avoid moisture buildup. It can be stored at a maximum of 14% water content. Grain:straw proportion is 1:1.5-1.7. Its average yield is 2-3.5 tons/ha.

2.1.3. Triticale (*X Triticosecale* Wittmack)

Triticale is a stable hybrid of wheat (*Triticum*) and rye (*Secale*). The basic aim of its production was to combine yield potential and grain quality of wheat with the disease and environmental tolerance of rye. Wheat is the female, rye is the male parent at crossing. Due to the sterility of the hybrid, usually colchicine is needed to induce polyploidy and reach fertility. Originally allooctoploid triticales were grown but their unfavorable characteristics (e.g. yield stability) could be avoided by allohexaploid triticales where tetraploid wheat species (e.g. *T. durum*) are applied as female parent.

Triticale had a growing area of 3,691,578 ha and a global production of 13,671,027 tons in the world (FAO, 2012).

Triticale is primarily used as feed grain but it has a potential in the production of products for human consumption, such as flour, bread, as well as energy and biomass crop.

Triticale has a remarkably high Mg, K, P, S, Ca, Mn, Zn, Fe, Se content. Its protein content is 12-16%, usually higher than that of wheat with low gluten proportion. The amino acid composition is good, e.g. lysine content is high.

Botanical characteristics

Morphologically triticale resembles its wheat parent, but partially exhibits the more vigorous growth characteristics of rye. Its root system development and plant height is between those of the parent species, and it tends to tiller less than wheat. The triticale spike resembles that of wheat more than rye, and is often larger than that of the parents. The

spike is composed of 30 to 40 spikelets. Each spikelet consists of 4 to 8 florets, of which usually only 3 are fertile (*Figure 11*). The lemmas generally taper into an awn of variable length. It is a self pollinating species but depending on the genotype, it is more susceptible to out-crossing compared to wheat. Its grains are usually brownish in color and slightly wrinkled in appearance. Its 1000 kernel weight is 40-45 g.



Figure 11 Triticale

Environmental requirements

Triticale prefers cool and humid climate but it has a good adaptability: it can be grown under conditions suitable for wheat or rye. Regarding optimal growing conditions, it is between wheat and rye. At ripening it requires moderate warm conditions. Earlier cultivars were grown on poor sandy soils due to their long stem but current varieties can be grown on soils of better quality without facing the problem of lodging. In general, it is worth cultivating under conditions resulting in more economical yield compared to wheat. These are the less favorable wheat soils that are, however, of better quality compared to those tolerated by rye, e.g. brown forest soils, medium-compact, meliorated meadow soils, sandy soils, alkaline soils, etc.

Table 11 Nutrient requirement of triticale

Nutrient uptake to 1 ton of grain				
N: 27 kg/t	P ₂ O ₅ : 12 kg/t	K ₂ O: 24 kg/t	CaO: 7 kg/t	MgO: 2 kg/t

Table 12 Sowing data of triticale

Sowing date:	
- winter wheat	15. September - 20. October
- spring wheat	20. February - 15. March
Row distance:	10.16 or 12 or 15.24 cm
Sowing depth:	4-6 cm
Seed rate:	4.5 - 5.2 million seeds/ha 200-250 kg/ha
1000 seed weight:	40-45 g

Cultivation

Triticale does not have special requirements regarding forecrops. It can be grown in monoculture for up to 3 years. Best forecrops are all those harvested early (see rye). Basic fertilization and sowing data can be found in *Tables 11* and *12*, respectively. In general, the effective ingredient doses are 100-130 kg/ha N, 70-80 kg/ha P and 80-100 kg/ha K. Tillage and crop care have the same aspects as listed for wheat.

Diseases and pest

Diseases and pest are basically the same listed for wheat and rye.

Harvesting

Triticale is harvested by a combine in fully ripe stage at moisture content below 16%. Grain loss must be below 4%. Triticale may be difficult to thresh due to its hard hulls. Its average grain yield is 3-6 tons/ha.

2.1.4. Barley (*Hordeum vulgare* L.)

Barley is the fourth largest cereal in the world regarding its growing area (49,525,988 ha). Due to its adaptability and the growing period of spring barley being the shortest among cereals, barley is cultivated worldwide. In northern countries (to the 70th latitude) this is the only cereal still ripening. It can be cultivated to altitudes of 1900 m (Alps) and 4000 m (Tibet). It is a widely used grain forage in subtropical countries. Agrotechnical advantages of barley are that it tolerates poor soil, small grain cereal forecrop and drought; it is excellent forecrop due to its early harvest; it utilizes nitrogen well, it has a low nitrogen requirement, shallow tillage is sufficient thus cost of production is low.

Its global production is 132,886,519 tons (FAO, 2012). Barley is used for the feeding of (primarily monogastric) livestock as grain forage (e.g. for pigs), the whole crop (in dough stage) as silage or dried, ground and granulated (GPS method), as well as its straw. In human consumption it is used as muesli, hulled barley, pearl barley and malt for beer and certain distilled beverages. Two-row barley has a lower protein content than six-row barley, thus possesses a more fermentable sugar content. Barley of high protein content is best suited for animal feed. Malting barley is usually low protein ('low grain nitrogen') showing more uniform germination, needing shorter steeping, and having less protein in the extract. Two-row barley is traditionally used in English ale-style beers and preferred for traditional German beers. Six-row barley is common in lager-style beers, especially when adjuncts (e.g. corn, rice) are used.

Barley has a high row fibre content (6, 4.5 and 1.3% for winter, spring and naked barley, respectively) which has a beneficial effect on the fat content of milk. For pig raising and human consumption (naked or dehulled) barley of lower fibre content is preferred. Crude protein content is 12-13.5%. Its lysine content (3.7%) is higher than that of wheat (2.8%).

Botanical characteristics

Basic characteristics are the same as mentioned at wheat. It has more seminal lateral roots and, according to the more intensive tillering, a higher number of nodal roots. Winter barley has a height similar to that of wheat while spring barley is 20-30 cm shorter with fewer tillers. Barley stems tend to be relatively weak that frequently leads to lodging in the last period of ripening, especially on the effect of heavy rain and storm. Especially prior to stem emergence, barley population shows a yellowish green color compared to the green color of wheat and rye. Considering spike structure, there are two main types of cultivated

barley: two-row and six-row. Both have three spikelets at each rachis node (one central and two laterals), each spikelet containing one floret. Lateral spikelets of two-rowed barley are sterile, resulting in two rows of (the central) kernels on the rachis. Six-rowed barley has all florets being fertile, resulting in six rows of kernels. Depending on genotype, lateral florets can be positioned the way that viewed in cross section only four rows can be seen (*Figures 12-13*). Awns may be smooth or barbed, longer or shorter relative to ear length. There also exist awnless geotypes, usually cultivated for green fodder purposes. Cultivated barley species are strictly self-pollinating. The lemma and palea adhere to the caryopsis in the case of hulled varieties. Hulled barley is "naked". Its seeds are released easily from the lemma and palea on threshing. Central kernels of six-row varieties are slightly larger and plumper than the lateral kernels, while those of the two-row varieties are all uniform in shape and size. The 1000 kernel weight is 38-42 g, 15-25% of this being hull. Its center of origin is the Fertile Crescent and Western Asia, the secondary centre of origin being Northeastern Africa. Barley belongs to the family Gramineae/Poaceae and it is diploid ($2n=14$).



Figure 12 Barley: 6-rowed (left), 2-rowed (right)

Environmental requirements

Winter barley

Winter barley is the crop of temperate climate, its growing period ranges from 250 to 270 days. It is less winterhardy than winter wheat, triticale or rye. Severe damages can be caused by a long and cold ($-15\text{ }^{\circ}\text{C}$) winter without snow cover, a strong fall in temperature following a warm period and an enduring snow cover. Winter barley has a moderate water requirement similar to that of wheat, however barley tolerates soil drought better than wheat. Precipitation in the period of germination and emergence has a significant importance in the determination of yield. Winter barley tolerates dry spring better than spring barley because it is harvested earlier thus the frightening of drought is lower. Dry March and April, however, can prolong stem elongation. Extreme precipitation in May can result in lodging and yield losses. Conditions making plants susceptible for frost damages and suffocation - such as wet soil, N-overdosage, frost-risk territories, shallow sowing depth, early sowing - should be avoided.

Winter barley is the crop of wheat soils of poorer quality. The best are the sandy, loose medium-compact meadow loam soils. It has a pH optimum of ca. 6. It can be grown on a wide range of soils, e.g. medium-compact or loose meadow and forest soils, good quality

sand, improved alkaline soils, moderately sloping and eroded soils. Wet, compact, cold soils, drift in sand, floodplains should be avoided.

Spring barley

Spring barley, especially if produced for malting purposes, prefers cool and humid climate. Its growing period is the shortest among small grain cereals ranging from 120 to 150 days. Required effective heat unit is 1300-1800 °C. Its germination starts at 1-3 °C. A gradual increase in temperature is preferred until reaching a moderate peak of 18-20 °C at ripening. If malting barley is produced, higher heat unit and higher temperature at ripening results in a decreased malting quality. It needs an annual precipitation of 550-600 mm, with 200-300 mm in the growing period. An even distribution of precipitation (ca. 40 mm/month) over the whole growing period is necessary with maximums in May and June (50-60 mm/month). Spring barley is a long-day plant thus early sowing is essential.

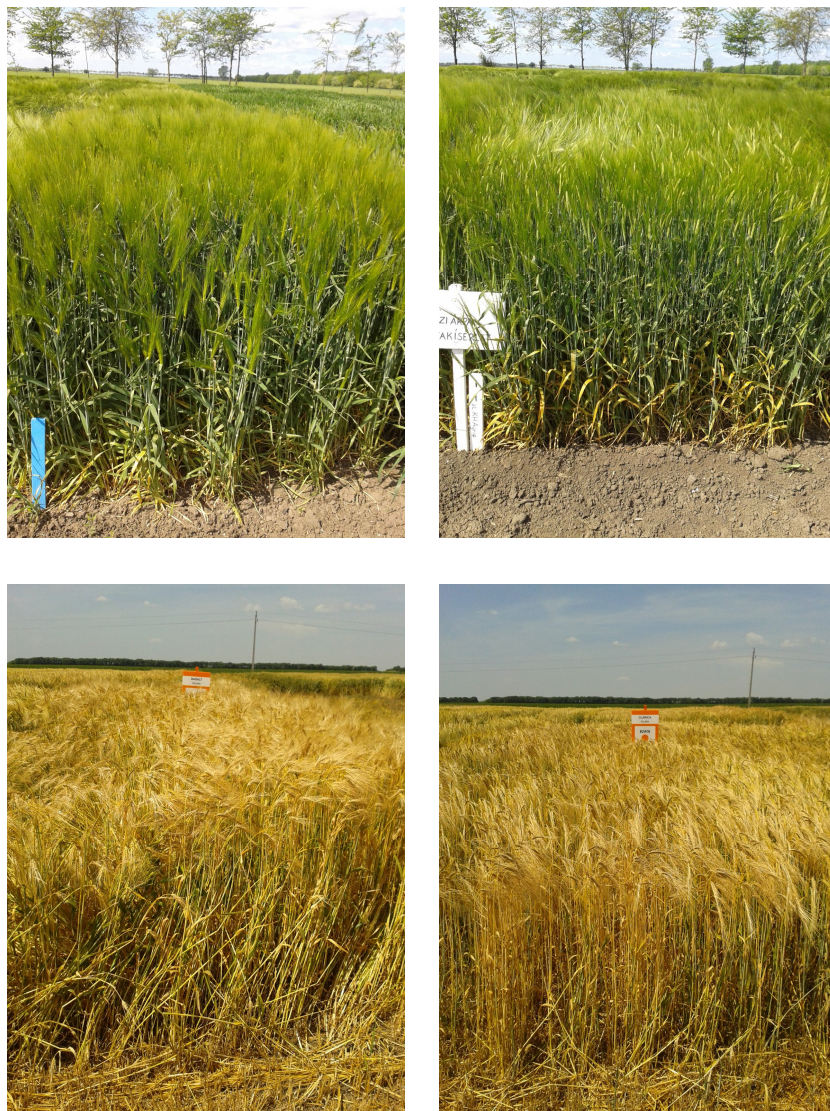


Figure 13 Barley populations: 6-rowed (left), 2-rowed (right)

Spring barley requires soils which make an early sowing possible. For malting barley fields of good capillary water leverage and homogenous subsoil, of good nutrient supply,

medium-compactness, good air and water management, deep fertile surface layer and a pH of 6.5-7.0 are preferred. In Western Europe it is cultivated on soils of best quality optimal for sugar beet. Acidic soils resulting in decreased yield and poor malting quality (thick hulls, less extract, etc.) must be avoided or improved by lime.

Table 13 Nutrient requirement of winter and spring barley

Nutrient uptake to 1 ton of grain					
winter barley	N: 27 kg/t	P ₂ O ₅ : 10 kg/t	K ₂ O: 26 kg/t	CaO: 6 kg/t	MgO: 2 kg/t
spring barley	N: 20 kg/t	P ₂ O ₅ : 9 kg/t	K ₂ O: 21 kg/t	CaO: 8 kg/t	MgO: 2 kg/t

Table 14 Sowing data of winter and spring barley

Sowing date: - winter barley - spring barley	20. September - 5. October 1-20. (30.) March
Row distance:	10.16 or 12 or 15.24 cm
Sowing depth: - winter barley - spring barley	3-6 cm 3-5 cm
Seed rate: - winter barley - spring barley	4.5 - 5.5 million seeds/ha 4 - 4.5 (5.5) million seeds/ha 160-250 kg/ha
1000 seed weight:	38-42 g

Cultivation

Winter barley

Winter barley is similar to winter wheat regarding the choice of forecrop. Best forecrops are all those harvested early, e.g. pea, rapeseed, flax, hemp, early potato. Winter barley itself is an excellent forecrop due to its early harvesting. It is good especially before rapeseed, catch crops (e.g. summer sown potato, sweet corn, green bean, forage rape, sudangrass, proso millet, buckwheat, foxtail millet) and green manure crops (e.g. oilseed raddish, lupins, mustard). Tillage and crop care have the same aspects as listed for wheat. Seed bed (8-10 cm depth) should be composed of small soil particles (<5 mm) and prepared 8-10 days prior to sowing to allow sedimentation. Root bed (below seed bed) should have a coarser structure composed of small clods that provides an appropriate pore volume. Basic fertilization and sowing data can be found in *Tables 13* and *14*, respectively. In general, the effective ingredient doses are 100-120 kg/ha N, 80-100 kg/ha P and 100-140 kg/ha K. Winter barley must not be sown too early to avoid suffocation damages and the late swarming of aphids as virus vectors. In several countries seeding rates of 2.5-3.5 million/ha are applied.

Spring barley

Best forecrops of spring barley are all those harvested early (e.g. flax, poppyseed, rapeseed, hemp, tobacco, early corn). Malting barley has special requirements. Best forecrop is sugar beet: it requires soil of good quality, does not increase soil N-content, leaves soil in good condition, free of weeds. Potato and silage maize are also preferred: no increase in N, early harvesting, little plant residues, no common pests and diseases. Crops

leaving much nitrogen in soil (legumes and pulses), small grain cereals and itself, sunflower and sorghums must be avoided. Tillage is the typical one described for crops sown early spring. Basic fertilization and sowing data can be found in *Tables 13* and *14*, respectively. In general, the effective ingredient doses for malting barley are 40-80 kg/ha N, 70-80 kg/ha P and 100-140 kg/ha K.

Diseases

Barley yellow dwarf virus (BYDV), powdery mildew (*Erysiphe/Blumeria graminis* f. ssp. *hordei*), barley brown rust (*Puccinia hordei*), loose smut (*Ustilago nuda*), false loose smut (*Ustilago nigra*), covered smut (*Ustilago hordei*), barley net blotch (*Drechslera/Pyrenophora teres*), barley leaf stripe (*Pyrenophora/Drechslera graminea/Helminthosporium gramineum*), spot blotch (*Cochliobolus sativus/Bipolaris sorokiniana/Helminthosporium sativum*), barley scald (*Rhynchosporium secalis*)

Pests

Frit fly (*Oscinella frit*), wheat bulb fly (*Hylemia/Phorbia/Delia coarctata*), barley gout fly (*Chlorops pumilionis*), cereal leaf beetle (*Oulema melanopus*), aphids (*Rhopalosiphum padi*, *Sitobion avenae*), stink bugs (*Euschistus spp.*), wheat grain beetle (*Anisoplia austriaca*), wireworms, armyworms, cutworms, mites

Harvesting

Barley is harvested by a combine in fully ripe stage at moisture content below 16%. Grain loss must be below 4-5%. The average yield is 4-5 (up to 7) tons/ha, with lower values for spring barley. Barley can be stored at a maximum of 14-14.5% water content.

On drying malting barley, drying temperature must not exceed 40 °C. In the malting barley crude protein of 10.6-11.6% (most countries) or 10.0-10.9% (UK) is required to achieve the malt specification for most brewers' needs. To realize good malting by plump, even sized kernels covered by an even husk without gape or splitting, the standard is 90% retained over a 2.5 mm screen (most countries) and 94% retained over a 2.25 mm screen (England and Wales).

2.1.5. Oat (*Avena sativa* L., *Avena nuda* L.)

Oat has a growing area of 9,608,318 ha and a global production of 21,062,972 tons in the world (FAO, 2012).

As livestock feed, it can be grain forage for horses and breeding animals, green forage (often as forage mix with e.g. spring vetch) or silage. It is suitable for grazing, furthermore its straw in whole or as flour, mixed with legumes. For human consumption, oat is primarily used as muesli, oatmeal and rolled oat.

Oat is considered to be a health food, recently due to its cholesterol-lowering properties. It has the highest content of soluble fibres among cereals resulting in slower digestion and an extended sensation of fullness. Beta-glucan, one type of soluble fibres can lower cholesterol content. Oat has high raw protein content (12-14%) with high avenalin and avenin proportion as well as beneficial amino acid composition. Oat protein is nearly equivalent in quality to soy protein. Oat has a high vitamin E and vitamin B₁ (also B₂ and B₆) content. It has the highest lipid content (5-7%) of cereals, except for maize. It has high metabolizable and digestible energy content.

Botanical characteristics

Basic characteristics besides inflorescence are the same as mentioned at wheat. It has a well-developed root system exhibiting the highest absorption capacity among small-grain cereals. Oats has a height similar to that of wheat. Unlike other small-grain cereals, oats has an inflorescence called panicle (*Figure 14*). The shape of the panicle can be equilateral or unilateral. Both the main axis and the alternate groups of branches arising from that terminate in a single spikelet. The number of spikelets per panicle ranges from 25 to 45 depending on genotype and growing conditions. Each spikelet contains from one to three (*A. sativa*) or up to eight (*A. nuda*) florets enclosed in glumes. Usually only the two basal florets are fertile. The flower is perfect with three stamens, a pistil and 2 lodicules. It is enclosed by two bracts, the lemma and palea. Flowering of oats starts in the uppermost flowers and extends downwards, from the outer florets inwards. The ripening of seeds is less equilibrated compared to spike. Similarly to barley, oats can be hulled (*A. sativa*) or hullless (*A. nuda*). The 1000 kernel weight is 28-32 g, 15-25% of this being hull. The center of origin of oats is the Fertile Crescent, Asia Minor and the Mediterranean region. Oats belong to the family Gramineae/Poaceae. Cultivated oats are allohexaploid ($2n=42$).

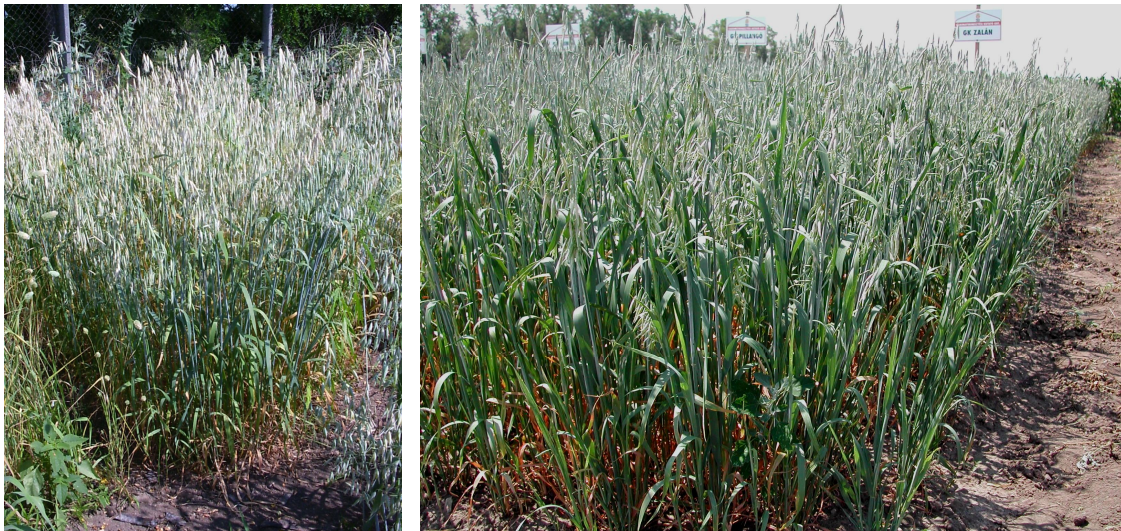


Figure 14 Oat

Environmental requirements

Oat is widely grown in temperate and sub-tropical regions but can also be cultivated in the high-altitude tropics. It prefers cool, moist climates, yet it is adapted to many climatic extremes. Oat is susceptible to damage by hot, dry weather if occurring during reproduction. The best areas for oat production have relatively cool summers. Its growing period is the longest among spring small grain cereals ranging from 160 to 180 days. Required effective heat unit is 1300-1800 °C. Its germination starts at 1-2 °C. In this period it has a frost tolerance to -5 °C. A gradual increase in temperature is preferred until reaching a moderate peak of 18-20 °C at ripening. It needs 250-300 mm precipitation with even distribution over the whole growing period. Appropriate amount of precipitation in the early stages is essential for a good yield. Precipitation in the later stages is, however, unfavorable due to promoting the development of secondary panicles that prolongs ripening and results in the loosening of grains in the primary panicles. Drought is the most dangerous during panicle development and grain filling.

Oat can be grown on most of the agricultural soils, except for the extreme poor ones. While responding to high fertility, oat will produce a crop on soils too poor and acid for wheat. Oat is less sensible for the raw soils brought to the surface via deepening tillage. Best soils are the moderately acidic (pH 5.3-6.4), medium compact soil of good water management such as cernozem and brown forest soils. Extreme compact, cold, alkaline and very loose sandy soil threatened by deflation should be avoided.

Table 15 Nutrient requirement of oat

Nutrient uptake to 1 ton of grain				
N: 28 kg/t	P ₂ O ₅ : 12 kg/t	K ₂ O: 29 kg/t	CaO: 6 kg/t	MgO: 2 kg/t

Cultivation

Triticale does not have special requirements regarding forecrops. Best forecrops of spring barley are all those harvested early (e.g. rapeseed, pulses, flax). Unfavorable are forecrops spreading common pests and pathogens, having high water and nutrient demands (e.g. small grain cereals, tobacco, potato, vegetables). Basic fertilization and sowing data can be found in *Tables 15* and *16*, respectively. In general, the effective ingredient doses are 60-70 kg/ha N, 40-50 kg/ha P and 120-140 kg/ha K. In several countries seeding rates of 2.0-3.0 million/ha are applied. Tillage and crop care have the same aspects as listed for spring barley. It can suppress weeds.

Table 16 Sowing data of oat

Sowing date:	
- spring oat	25. February – 15. (25.) March
- winter oat	15–30. September (early October)
Row distance:	10.16 or 12 or 15.24 cm
Sowing depth:	
- spring oat	3-5 cm
- winter oat	4-6 cm
Seed rate:	(4) 4.5 - 5 million seeds/ha 160-180 kg/ha
1000 seed weight:	28-32 g

Diseases

Barley yellow dwarf virus (BYDV), crown rust (*Puccinia coronata* f. ssp. *avenae*), Helminthosporium leaf blotch (*Drechslera avenae*), loose smut (*Ustilago avenae*), covered smut (*Ustilago keller*), stem rust (*Puccinia graminis* f. ssp. *avenae*), common root rot (*Cochliobolus sativus/Bipolaris sorokiniana/Helminthosporium sativum*), halo blight (*Pseudomonas syringae* pv. *coronafaciens* or *P. syringae* pv. *striaefaciens*), leaf blotch (*Pyrenophora avenae*), septoria leaf blotch (*Septoria avenae* f.sp. *avenae/Phaeosphaeria avenaria/Stagonospora avenae*), fusarium head blight (*Fusarium graminearum*)

Pests

Same as for wheat and barley.

Harvesting

Oat has an extended ripening period. Harvesting should be started when grains in the uppermost third of the panicle are in full ripening (14-15% moisture content). This time the

seeds in the lower part are in physiological ripening, exhibiting 2-3% higher moisture content. Its average yield is 2.5-5 tons/ha. Due to its high lipid content (5-7%), the waterloss after harvesting is slow. To avoid moisture buildup, grains must be regularly mixed and aerated during storage. Grain:straw proportion is 1:1.5-2.0.

2.1.6. Maize/Corn (*Zea mays* L.)

Maize is the second largest arable crop in the world regarding its growing area (177,379,507 ha plus 1,125,916 ha green maize). Its global production was 872,066,770 tons plus 9,764,006 tons for green maize (FAO, 2012).

Maize can be utilized several ways for feed (e.g. grain, silage, Corn-Cob Mix /CCM/, Ground Ear Maize /GEM/), food (e.g. baby corn, sweet corn, popcorn, cornflakes, flour, starch, cooking oil, syrup, alcohol) and other purposes (e.g. bioethanol, biomass-biogas).

Maize has a high starch content (65%) while it contains relatively low levels of crude protein (7-9%). The amino acid composition is less favorable compared to several other cereals. Its germ contains 3-5% valuable oil.

Botanical characteristics

The root system of maize can be divided into embryonic and postembryonic roots. The embryonic root system consists of a primary root and a various number of seminal roots. The postembryonic root system is composed of shoot borne roots formed at consecutive shoot nodes (including aboveground brace roots) and lateral roots initiated at the pericycle of all roots. Maize stems are erect, conventionally 2–3 m in height, composed of ca. 20 internodes, casting off leaves at every node. Between the stem and leaf sheath develop the ears. These are female inflorescences, tightly covered over by several layers of ear leaves (husks). Elongated stigmas (silks) emerge from the whorl of husk leaves at the end of the ear. The apex of the stem ends in the tassel, an inflorescence of male flowers. An ear contains from 200 to 400 kernels, and is from 10–25 centimetres in length (*Figure 15*). The 1000 kernel weight of corn is between 100 and 400 g, depending on the genotype and seed fraction (SF – small flat, SR – small round, LF – large flat, LR – large round).



Figure 15 Maize

Several forms of maize are used for feed and food, classified as various subspecies related to the amount of starch each had:

- Dent corn - *Zea mays* var. *indentata*
- Flint corn - *Zea mays* var. *indurata*
- Sweet corn - *Zea mays* var. *saccharata* and *Zea mays* var. *rugosa*
- Popcorn - *Zea mays* var. *everta*
- Flour corn - *Zea mays* var. *amylacea*
- Waxy corn - *Zea mays* var. *ceratina*
- Amylomaize - *Zea mays*
- Pod corn - *Zea mays* var. *tunicata* Larrañaga ex A. St. Hil.
- Striped maize - *Zea mays* var. *japonica*

According to the extended BBCH-scale, maize has the following principal phenological growth stages:

- 0: Germination
- 1: Leaf development
- 3: Stem elongation
- 5: Inflorescence emergence, heading
- 6: Flowering, anthesis
- 7: Development of fruit
- 8: Ripening
- 9: Senescence

Maize is a protandric species, male flowers blooming prior to the female ones on the same plant to avoid self-fertilization. Its pollen is anemophilous (dispersed by wind). Maize is a facultative short-day plant and flowers in a certain number of growing degree days $> 10\text{ }^{\circ}\text{C}$ in the environment to which it is adapted.

The center of origin of maize is Mexico and Mesoamerica, the secondary center being South America. Maize belongs to the family Gramineae/Poaceae and it is diploid ($2n=20$).

Today, hybrids based on various combinations of inbred lines are used in maize growing:

- Single cross (SC): $A \times B$
- Modified SC (MSC): $(A \times A') \times B$ (A' is a "sister-line" of A)
- Three-way cross (TC): $(A \times B) \times C$
- Modified TC (MTC): $(A \times B) \times (C \times C')$ (C' is a "sister-line" of C)
- Double cross (DC): $(A \times B) \times (C \times D)$

Highest level of hybrid vigor can be expected with SC hybrids. DC hybrids are the least expensive and they are usually used as forage (silage).

Genetically modified (GM) hybrids resistant to glyphosate or glufosinate herbicides as well as possessing insect resistance by *Bt* toxins are also cultivated in several countries.

Environmental requirements

Maize is a warm weather crop and is not grown in areas where the mean daily temperature is less than $19\text{ }^{\circ}\text{C}$ or where the mean of the summer months is less than $23\text{ }^{\circ}\text{C}$. Although the minimum temperature for germination is $10\text{ }^{\circ}\text{C}$, germination will be faster and less variable at soil temperatures of 16 to $18\text{ }^{\circ}\text{C}$. Hardy varieties can grow already at a lower temperature of 6 - $8\text{ }^{\circ}\text{C}$. Frost can damage maize at all growth stages and a frost-free period of 120 to 140 days is required to prevent damage. Its most sensible developmental period is between heading (tasseling) and the development of kernels with an optimum temperature of 24 - $26\text{ }^{\circ}\text{C}$ and the the maximum of water uptake (100 - 100 mm in July and in August). Its total water requirement is 450 - 550 mm (daily water consumption is 4.5 - 5.5 mm/ha).

Maize varieties are grouped several ways regarding the length of their growing period. One method uses the so-called FAO index/number (*Table 17*) but the grouping system can depend on company and country, too.

Among cereals maize requires the best soil conditions. Because of its shallow roots, it is susceptible to droughts, intolerant of nutrient-deficient soils, and prone to be uprooted by severe winds. The most suitable soil for maize is one with a good effective depth, favourable morphological properties, good internal drainage, an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties that are favourable specifically for maize production. Its pH optimum is between 6.6 (5.8) and 7.5 (8.0).

Table 17 Approximate heat unit requirements by FAO index groups

Maturity group	FAO index	Heat Unit (°C)
Very early	100-199	916-972
Early	200-299	1028-1088
Mid-early	300-399	1138-1194
Half-late	400-499	1250-1305
Late	500-599	1361-1417
Very late	600-699	1472-1528

Cultivation

Maize does not have special requirements regarding forecrops. It can be grown even in monoculture for several years but rotation is an effective method of prevention against several pests such as western corn rootworm. Best forecrops are small grain cereals, pulses, legumes, rapeseeds and other crops harvested early. Basic fertilization and sowing data can be found in *Tables 18* and *19*, respectively.

Table 18 Nutrient requirement of maize

Nutrient uptake by 1 ton of grain and dry stalk					
Grain maize	N: 28 kg/t	P ₂ O ₅ : 11 kg/t	K ₂ O: 30 kg/t	CaO: 8 kg/t	MgO: 3 kg/t
Nutrient uptake by 1 ton of green mass					
Forage maize	N: 3.5 kg/t	P ₂ O ₅ : 1.5 kg/t	K ₂ O: 4.0 kg/t	CaO: 2 kg/t	MgO: 0.7 kg/t

Table 19 Sowing data of maize

	Grain maize	Forage maize
Sowing date:	15. April-05. May	15. April-15. May
Row distance:	70-76.2 cm	
Sowing depth:	5-8 cm	
Seed rate:		50-100,000 seeds/ha
- FAO 200-300	70-80,000 seeds/ha	
- FAO 400	65-70,000 seeds/ha	
- FAO 500	60-65,000 seeds/ha	
	4.5-6.0 seeds/m of row	3.9-7.0 seeds/m of row
	10-20 kg/ha	20-40 kg/ha
1000 kernel weight:	100-400 g	

Inter-row cultivation can be used to improve soil structure and as an alternative or supplement to chemical weed control by herbicides.

Under continental climate, fodder maize is rarely irrigated due to economical reasons. If it is applied, irrigation must be performed prior to heading (50-60 mm), followed by 2-3 x 30-40 mm (12-14 days of rotation) and 50-60 mm at grain filling.

Diseases

Corn/common smut (*Ustilago maydis*), maize dwarf mosaic virus (MDMV), *Fusarium graminearum*, *Fusarium verticilloides*, common rust (*Puccinia sorghi*), *Helminthosporium maydis*

Pests

Cotton bollworm (*Helicoverpa armigera*), European corn borer, ECB (*Ostrinia nubilalis*), corn weevil (*Tanymecus dilaticollis*), fall armyworm (*Spodoptera frugiperda*), western corn rootworm (*Diabrotica virgifera virgifera* LeConte), aphid (*Tetraneura ulmi*)

Harvesting

Grain corn Grain corn is harvested by a combine at a moisture content below 20% if possible. In the case of varieties belonging to the half-late or later maturity group, this value is usually higher. Grain corn can be stored at 14-14.5% water content. Its average yield is 4-9 tons/ha.

Forage maize Forage harvesters chop forage maize and also crack kernels. Harvesting forage maize between 28 and 32% dry matter content (grains: 35-38% moisture content, dough stage) promises the ideal combination of digestibility, starch content and dry matter yield factors. The best indicator of dry matter yield and silage quality is in the milk line score. At late grain fill stage, there is a visual line of separation between the starchy tip and the milky base of individual grains. The line moves down the grain towards the core of the cob over a six-week period (approximately). Optimal time for harvesting is when this milk line is half way down the length of individual grains.

Corn-Cob Mix (CCM) The entire cob is harvested with a traditional forager using a picker header. The resulting product is slightly lower in energy density than crimped maize grain, but because it contains the spindle and husk, it provides a useful source of added fibre. CCM - which takes the cob and sheath - can be ready for harvesting 10-14 days after optimum timing for silage. Agronomically there's no difference in the management regime for CCM compared to maize silage. Preservative is added at harvest, producing a ready to ensile feed, without then need for a crimping machine. Another advantage is that it can be harvested 10-14 days earlier than crimping, but avoids clashing with the regular forage maize window.

Ground Ear Maize (GEM) CCM differs from GEM in that a portion of the leaf around the cob is also present in the mix, adding to its scratch factor in the cattle's diet. Ground ear maize is forage produced by ensiling the chopped maize ear and is harvested using a cob picker header mounted on a forage harvester. At harvesting the plant stems are pulled down through the header, chopped and spread over the soil. The cobs however are 'snapped' off the stem during this process and continue through the harvester where they are chopped.

2.1.7. Sorghums (*Sorghum spp.*)

Worldwide, sorghum is a food grain for humans. Parallel, in several countries sorghum is used primarily as a feed grain for livestock.

Feed value of grain sorghum is similar to corn. The grain has more protein and fat than corn, but is lower in vitamin A. Grain sorghum feeding value ranges from 90% to nearly equal to corn. The grain is highly palatable to livestock, and intake seldom limits livestock productivity. However, some sorghum varieties and hybrids which were developed to deter birds are less palatable due to tannins and phenolic compounds in the seed. The grain should be cracked or rolled before feeding to cattle; this improves the portion digested. Its grain yield is 1.5-2.0 (9.0) t/ha.

Forage sorghum silage is usually slightly lower in energy than corn silage and is similar in protein. Forage sorghum usually does not regrow following harvest, unlike sudangrass, so it is best adapted to a single-cut harvest for silage. Sudan grass hybrids fit best in summer feeding programs. They are thick stemmed and hard to dry for hay but they can supply ample yields of silage, green chop and pasture when perennial grasses are slowing down or going dormant. Its green mass is 30-50 (80) t/ha.

Sudan grasses yield slightly lower than corn when harvested for silage, but they have the advantage that they can be cut 2-3 times during the season and can also be stored as either chopped silage or wrapped bale silage, green chopped or pastured. Corn silage produces more tons per hectare but it must be harvested in the fall with specialized forage harvesting equipment. Sudan grasses can also be harvested using a strip grazing system. They are thus more versatile to harvest than corn. Its potential green mass can reach 100 t/ha/year, dry yield is 18-25 t/ha.



Figure 16 Grain sorghum (left), forage sorghum (centre), sudan grass (right)

Botanical characteristics

Sorghums are warm season grasses known for being drought resistant. They are more efficient in water absorption because they have twice as many secondary roots per unit of primary root as corn and have only half as much leaf area as corn for evaporation. Their water requirements are the same as corn but they have the ability to go dormant during extended drought periods. Growth will begin when the rains come.

Grain sorghum (*Sorghum bicolor* /L./ Moench) Grain sorghum is a grass similar to corn in vegetative appearance, but sorghum has more tillers and more finely branched roots than

corn. Growth and development of sorghum is similar to corn, and other cereals. Sorghum seedlings are smaller than corn due to smaller seed size. The grain sorghum head is a panicle, with spikelets in pairs. Sorghums are normally self-fertilized, but can cross pollinate. Hybrid sorghum seed is produced utilizing cytoplasmic male sterility. Sorghum can branch from upper stalk nodes. If drought and heat damage the main panicle, branches can bear panicles and produce grain. The grain is free-threshing, as the lemma and palea are removed during combining. The seed color is variable with yellow, white, brown, and mixed classes in the grain standards. Brown-seeded types are high in tannins, which lower palatability (*Figure 16*).

Forage sorghum (*Sorghum dochna* /F./ Snowden var. *saccharatum*) Forage sorghum hybrids have sweet juicy stems (juice: 70-80%, sugar: 18-22% of juice). They produce less than Sudan grass hybrids and have very slow regrowth. They have been selected for one-time harvesting. A sorghum hybrid should be harvested in the soft dough stage for maximum forage production (*Figure 16*).

Sudan grass (*Sorghum sudanense* /P/ Stapf) This is a fine stemmed and leafy plant with very quick regrowth. It is best used for pasture or in multiple cut systems. If used in a one cut system, yields will be less than that of forage sorghum. Forage quality will be high due to low fiber content if cut frequently (*Figure 16*).

The center of origin of sorghums is East and Central Africa. Sorghums belong to the family Gramineae/Poaceae and they are diploid (2n=20).

Environmental requirements

Low temperature, not length of growing season, is the limiting factor for production. For germination sorghum requires a soil temperature of 12-16 °C. Average temperatures of at least 21 °C during July are needed for maximum yields.

Sorghum is more tolerant of wet soils and flooding than most of the grain crops. It is drought tolerant. Most of the poorly drained, wet soils are too cold for grain sorghum. Optimal pH is between 5.5 and 8.5.

Table 20 Nutrient requirement of sorghums

Nutrient uptake by 1 ton of grain and straw					
Grain sorghum	N: 29 kg/t	P ₂ O ₅ : 10 kg/t	K ₂ O: 31 kg/t	CaO: 8 kg/t	MgO: 3 kg/t
Nutrient uptake by 1 ton of green sorghum stalk					
Forage sorghum	N: 3.1 kg/t	P ₂ O ₅ : 1.4 kg/t	K ₂ O: 3.2 kg/t	CaO: 1.5 kg/t	MgO: 0.5 kg/t
Nutrient uptake by 1 ton of green mass					
Sudan-grass	N: 2.6 kg/t	P ₂ O ₅ : 1.2 kg/t	K ₂ O: 3.5 kg/t	CaO: 1.0 kg/t	MgO: 0.5 kg/t

Cultivation

A seedbed similar to the one prepared for corn is also good for sorghum. The use of a cultipacker or corrugated roller after seeding often gives better stands. In warmer regions, reduced- and no-tillage systems can be used. Basic fertilization and sowing data can be found in *Tables 20* and *21*, respectively.

A popular and effective mode of cultivation is sowing forage maize and forage sorghum in a combination of 2 + 2 rows (*Table 22*). It has a beneficial effect especially under arid conditions because maize keeps green longer, otherwise the juicier green mass of sorghum compensates that of maize drying earlier.

Table 21 Sowing data of sorghums

	Grain sorghum	Forage sorghum	Sudan grass
Sowing date: - main crop - second crop	25. April-10. May -	5-15. May -	25. April-10. May until 10. July
Row distance: - grain - green chop	50-70 cm -	50-70 cm	12 or 24 cm
Sowing depth:	3-6 cm	3-5 cm	2-4 cm
Seed rate:	200-400,000 seeds/ha 10-20 kg/ha	200-300,000 seeds/ha 10-14 kg/ha	1-2 million seeds/ha 25-35 kg/ha
1000 kernel weight:	30-34 g	28-33 g	20-22 g

Table 22 Sowing data of forage maize and forage sorghum combination

	Forage maize	Forage sorghum
Sowing date:	20. April-10. May	
Row distance:	70-76.2 cm	
Sowing depth:	5-6 cm	2-3 cm
Seed rate:	50,000 seeds/ha 5 seeds/m of row	120,000 seeds/ha 8 seeds/m of row
1000 kernel weight:	200-400 g	28-33 g
Harvesting date:	20. August-15. September	
Green mass:	30-40 t/ha	

Harvesting

Grain sorghum is harvested as a standing crop with a combine. Combining time will depend on the fall weather. Sorghum grain can be threshed free of the head when the seed moisture is 20-25%. Frost will generally kill the top of the plant and help to lower the moisture content. Sorghum seed is easily damaged in the threshing operation, especially when the grain is dry.

The grain sorghum crop can be harvested for high-moisture grain silage. When fed to livestock, its digestibility will be increased by grinding or rolling. High moisture grain sorghum can be combined and ensiled when the grain is about 25-30% moisture.

The first Sudan grass cut is ready for harvest about 60 days from planting. The plants should be ca. 90-120 cm in height, and just before head emergence when cut. For a faster recovery of aftermath growth, leave at least 10 to 18 cm of stubble when harvesting. Optimum growth of these plants occurs under hot, moist conditions. A second cut should be ready 30-35 days later. At cutting, the crop is about 70-75% moisture and requires wilting before ensiling. To promote fermentation, additives of high dry matter content (e.g. alfalfa, corn) can be added.

Sudan grass may be pastured but livestock should not enter before the plants are 45 cm high. Trampling damage will be very high unless a strip or rotational grazing system is used. As the plants will reach this height by mid summer and are drought resistant, this can provide a source of feed during the summer slump of pastures.

Feed quality and animal health hazards. Once Sudan grass begins to head out, the quality and feeding value drop drastically. As the crop matures, protein content drops rapidly (from 17 to 8%), while fibre levels increase. This decreases the feed energy value and rumen digestibility. Sudangrass can contain as much protein as mature alfalfa, but only if harvested at the vegetative stage. Energy levels in vegetative material are similar to corn and higher than alfalfa.

Prussic acid poisoning. Sorghum species contain various amounts of cyanogenic glucosides. In the rumen, these compounds are converted into prussic acid, which is readily absorbed into the blood. High blood levels of prussic acid interfere with respiration and cattle can soon die from respiratory paralysis. Horses should not be allowed to graze these plants as they may develop cystitis syndrome. There is no treatment for this poisoning and poor prognosis of recovery.

Management practices that can reduce risk of prussic acid poisoning:

- Graze or green chop only when forage is greater than 45 cm tall for sudangrass or greater than 55 to 65 cm for forage sorghum hybrids.
- Do not graze plants during or immediately after a drought, or where growth has been reduced; on nights when a frost is likely. High levels of the toxic compounds are produced within hours after a frost occurs; after a killing frost until the plant is dry and brown cyanogenic glucosides usually dissipate within 7 days and after a non-killing frost until regrowth is at least 45 cm tall.
- Do not green chop or ensile the forage for 3 to 5 days after a killing frost.
- Allow forage to ensile for at least 3 weeks before feeding.

Nitrate poisoning and formation of toxic silo gas. High nitrate levels are only a problem under abnormal growing conditions. High nitrate levels will persist in forages cut for hay, but will be reduced by 50% when ensiled for 30 to 60 days. When high nitrate forage is ensiled, deadly nitrogen dioxide gas (silo gas) can be produced within hours, and be a concern for at least 3 weeks.

In spite of these potential problems with Sorghum-Sudan grass, it is a good emergency forage during summer conditions. Its quality is variable, making its feeding value more suited to low producers, dry cows and heifer replacements. It provides an alternative feed source during the summer months when existing pastures may be producing less, or may be a valuable feed supplement until other forages are ready.

2.1.8. Proso millet (*Panicum miliaceum* L.) and foxtail millet (*Setaria italica* L.)

The term millet is applied to various grass crops whose seeds are harvested for food or feed. The five millet species of commercial importance are proso, foxtail, barnyard (*Echinochloa frumentaceae* L.), browntop (*Panicum ramosum*) and pearl (*Pennisetum glaucum*). Millets are some of the oldest of cultivated crops. In China, records of culture for foxtail and proso millet extend back to 2000 to 1000 BC.

The major uses of proso millet are as a component of grain mixes for parakeets, canaries, finches, lovebirds, cockatiels and wild birds and as feed for cattle, sheep, hogs and poultry. Large bright or red seed is preferred. Proso millet as livestock feed is similar to oats and barley in feeding value. It is commonly fed in ground form to cattle, sheep, and hogs. Whole seed can be fed to poultry. The protein values compare favorably with sorghum and wheat and are higher than corn. Proso also has considerably higher fiber levels, due to attached hulls. Proso performs best in livestock rations when fed in mixtures with other grains. If the amino acid levels are balanced, the feeding value to hogs is nearly equal to corn. Proso can be cut for hay, but it is not as suitable as foxtail for this purpose.

Foxtail millet is usually grown for hay or silage often as a short-season emergency hay crop. Some seed is used for finch and wild bird feeds. It does not necessarily yield more forage than proso but is free of foliage hairs and is finer stemmed. For forage, foxtail millet is harvested at the late boot to late bloom stage. Foxtail millet should not be fed to horses as the only source of roughage since it acts as a laxative. If foxtail millet has been severely stressed it may accumulate nitrate at levels toxic for livestock.

Botanical characteristics

Millet is an annual grass. Proso millet grows to a height of approximately 1 m and has a hollow stem. Both stems and leaves are curved with short hairs. Proso millet has a large, open panicle inflorescence. When the grain is threshed, most of the seed remains enclosed in the inner hull. Hulls are extremely variable in color and, depending on the variety, may be white, red, yellow, brown or striped (*Figure 17 left*).

Foxtail millet has slender, erect leafy stems and may grow up to 1.25 m tall. The inflorescence is a dense, bristly panicle resembling the panicles of weedy foxtails. As in proso millet, the seeds are enclosed in the hull and also range in color from creamy white, red, yellow or dark purple (*Figure 17 right*). Both proso and foxtail millet are highly self-pollinated but have been known to occasionally outcross. Proso and foxtail millet are short season crops.

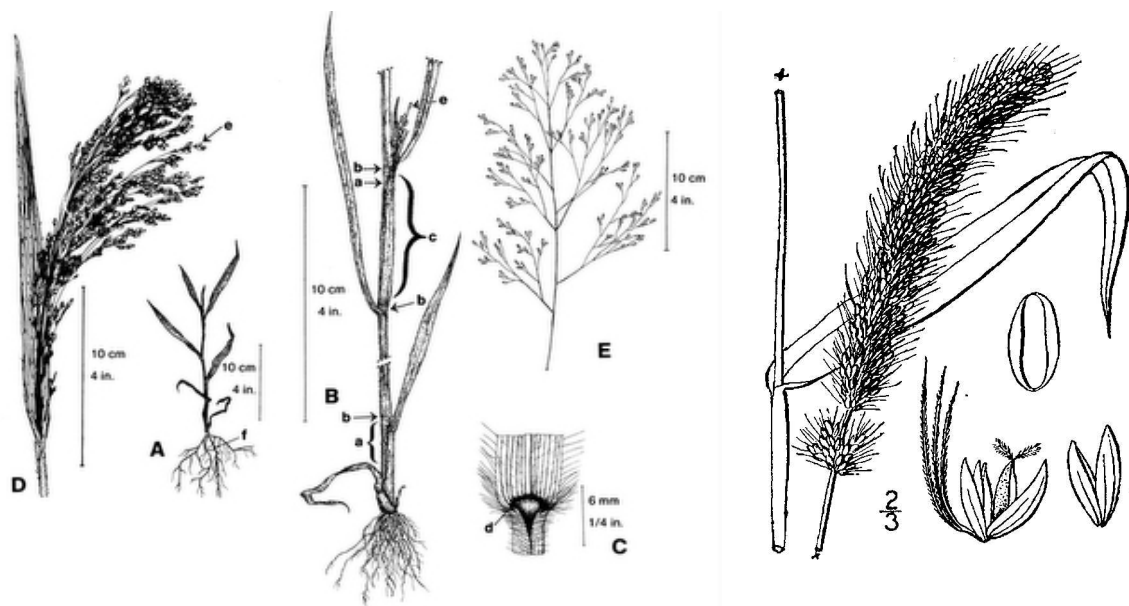


Figure 17 Proso millet (left) and foxtail millet (right)

The center of origin of proso millet is central and eastern Asia, the secondary centre of origin being India, Russia, the Middle East and Europe. Proso millet belongs to the family Gramineae/Poaceae and it is diploid ($2n=36$), largely self-pollinated plant.

The center of origin of foxtail millet is China. Foxtail millet belongs to the family Gramineae/Poaceae and it is diploid ($2n=18$), largely self-pollinated plant.

Environmental requirements

Millets require warm temperatures for germination and development and are sensitive to frost. Optimum soil temperatures for seed germination are between 20 and 30 °C. Proso and foxtail millet are efficient users of water and grow well in areas of low moisture, partly because they are early and thereby avoid periods of drought. Millets are often grown as

catch crops where other crops have failed or planting is delayed due to unfavorable weather.

Millets grow well on well-drained loamy soils. They will not tolerate water-logged soils or extreme drought. Proso millet does not perform well on coarse, sandy soils. A pH of 5.6 or higher is recommended for millet.

Table 23 Nutrient requirement of millets

	Nutrient uptake, kg/t				
Green forage	N: 3.1	P ₂ O ₅ : 1.3	K ₂ O: 3.4	CaO: 1.5	MgO: 0.4
Grain:	N: 25	P ₂ O ₅ : 10	K ₂ O: 21	CaO: 11	MgO: 3

Cultivation

Seedbed preparation for millet is similar to that for spring-seeded small grains. Weeds should be controlled prior to planting and the seedbed should be firm and well-worked. Since millets are planted late in the season, spring plowing and cultivation for weed control are practical. Basic fertilization and sowing data can be found in *Tables 23* and *24-25*, respectively.

Table 24 Sowing data of proso millet

	Proso millet
Sowing date:	10. May-10. July
Row distance:	12 cm
Sowing depth:	1-1.5 cm
Seed rate:	7-8.5 million seeds/ha 84-102 seeds/m of row
1000 seed weight:	
- red	4.5-5.0 g
- yellow	5.5-6.0 g

Table 25 Sowing data of foxtail millets

	Common foxtail millet	Red grained foxtail millet	Tall foxtail millet
Sowing date:			
- main crop	15-31. May	15-31. May	1-15. May
- second crop	20. June-10. July	1-10. June	1-30. June
Row distance:			
- seed	24 cm	24 cm	36 cm
- seed, twin-row	-	2x12-2x36 cm	2x12-2x48 cm
- forage	12 cm	12 cm	24 cm
Sowing depth:	1.5-2 cm	1-2 cm	1.5-2 cm
Seed rate:			
- seed	6 million seeds/ha 144 seeds/m of row	7 million seeds/ha 168 seeds/m of row	6 million seeds/ha 217 seeds/m of row
- forage	9 million seeds/ha 216 seeds/m of row	10 million seeds/ha 240 seeds/m of row	8 million seeds/ha 290 seeds/m of row
1000 seed weight:	2-2.2 g	2.5 g	3 g

Diseases

BYDV, head smut (*Sphacelotheca destruens*), kernel smut (*Ustilago crameri*), millet rust (*Puccinia purpurea*), *Fusarium spp.*

Pests

European corn borer (*Ostrinia nubilalis*), frit fly (*Oscinella frit*), grasshoppers, armyworms

Harvesting

Proso millet is ready for harvest when seeds in the upper half of the panicle are mature. Seeds in the lower half of the panicle may still be in the dough stage but should have lost their green color. At this point, the leaves and stems may still be green. Millet is usually harvested by swathing to allow drying of straw before combining. Swathing too early reduces yield, test weight and color quality. Harvesting too late increases loss as a result of shattering and lodging. Rodents and birds can cause damage to proso during ripening. Control programs are often needed. Millet seed should be stored at 13% moisture or less.

Foxtail millet should be harvested for hay or silage from the late boot to bloom stage. At this stage, hay quality is at its peak, and protein levels of 12 to 14% may be common. As the plant matures, protein declines. Also mature bristles from delayed harvest may cause lump jaw and sore eyes in cattle feeding from bunks. When harvesting foxtail millet for seed production, it should not be cut until completely ripe, then swathed and threshed. Sometimes it is direct combined after a killing frost, but some seed loss will occur.

2.1.9. Rice (*Oryza sativa* L.)

Rice is the third most important cereal in the world based on the sowing area (until the end of the 2000s it was the second one). It is primarily used as food: brown (whole grain, hulled) or white (hulled and polished) rice, rice debris (for spirit and starch production), rice flour/powder (in canned and baby food, food for people suffering celiac disease, etc.), etc. Bran and other by-products of hulling are used for both food and animal feeding. Husks removed at hulling can be utilized for feeding, for soil improvement, as litter, as filter material, etc. Straw gives raw material for cellulose processing, rope production, etc. Protein content of rice (7.5%) is lower than that of wheat, however its essential amino acid composition is better, similar to that of animal proteins. Rice contains high levels of dietary fibres (14%), vitamins B₁, B₃, B₆, as well as iron, magnesium, manganese, selenium and zinc. The beneficiary nutritional value of rice is mainly lost via the removal of bran layer (polishing) from brown rice. Its starch is easily digestible.

Botanical characteristics

Rice has four major categories worldwide (with overlaps between the different types): indica (non-sticky, long-grained; grown mainly submerged in tropical areas), japonica (sticky, short-grained; grown in sub-tropical and temperate areas), aromatic (medium to long-grained of nut-like taste and aroma: e.g. basmati, jasmine rice), glutinous (sticky/sweet/waxy rice of low amylose content mainly grown in Southeast and East Asia). Rice is an annual grass. Its general morphological characteristics and growth stages resemble those of other small grain cereals. It can be 0.8-1.8 m tall. Its inflorescence is a panicle (*Figure 18*). Caryopses are covered by husk which cannot be removed via threshing. Removal of husks (husking) results brown rice. Polishing removes the outer bran layer of kernel resulting white rice. 1000 kernel weight of rice is 25-35 g.

The centres of origin of rice are supposed to be South-eastern Asia (India, Myanmar and Thailand) and West Africa. Rice is a diploid ($2n=12$), primarily self-pollinating plant.



Figure 18 Rice

Environmental requirements

Rice is a warm demanding crop. It can be safely grown to 40° latitude. Under temperate climate its growing period is 130-150 days and the cumulative seasonal heat unit is 2600-3000 $^{\circ}\text{C}$ although e.g. in Hungary it reaches only 1400-1500 $^{\circ}\text{C}$. Regarding temperature, the critical growth stages are germination (12-14 $^{\circ}\text{C}$), tillering (16-18 $^{\circ}\text{C}$), flower development and flowering (20-22 $^{\circ}\text{C}$). Large fluctuations in temperature cause stress resulting in increased panicle sterility. Insolation has less effect on yield elements during the vegetative development but its effect increases during the reproductive stage, it has positive correlation with yield. Precipitation has indirect effect on rice development.

Rice has unique requirements regarding soil quality. It needs soils of poor water permeability with aquitard close to soil surface. Total salt content must not exceed 0.4-0.6%, soda content 0.1%. The pH optimum is 5-6. Meadow, meadow solonetz and solonetz meadow soils work well.

Rice is hygrophyte that does not require much water but water must be available in sufficient amount in the course of the whole growing period. Besides providing water continuously, the traditional method of flooding the fields act as temperature buffer under temperate climate, furthermore it reduces the growth of weed plants and deters several other pests.

Cultivation

Traditionally, rice is cultivated in monoculture. Under temperate climate (e.g. in Hungary), however crop rotation is preferred. Thus rice is cultivated in monoculture for 3-5 years, followed by fallow and occasionally manuring. It can be followed by (perennial) legumes, then small grain cereals or rape. In Hungary the paddy fields of 30-50 ha are traditionally divided into parcels of 4-6 ha. Tillage in the dry period serves the drying of the tilth of soil and the control of weeds. Care must be taken not to mix subsoil of high salt concentration into the upper layer.

Basic fertilization and sowing data can be found in *Tables 26* and *27*, respectively. In general, the effective ingredient doses are 70-120 kg/ha N, 50-80 kg/ha P and 40-50 kg/ha

K. Rice takes up nitrogen primarily in the form of ammonium thus nitrogen should be supplied with ammonium fertilizers.

Table 26 Nutrient requirement of rice

Nutrient uptake, kg/t				
N: 25	P ₂ O ₅ : 12	K ₂ O: 32	CaO: 6	MgO: 2

Table 27 Sowing data of rice

Sowing date:	15-30. April (until early May)
Row distance:	10.16 or 12 or 15.24 cm
Sowing depth:	3-4 cm
Seed rate:	4.5 - 6 million seeds/ha 150-190 kg/ha
1000 seed weight:	25-35 g

Rice can be sown in various ways: into the soil, on soil surface, into water or it can be grown from seedlings. Sowing into soil is preferred due to the rapid growth of plants and the ease of weed and pest control. It requires a soil temperature of 12 °C. The field is flooded at the growth stage of 2-3 leaves. Sowing on the soil surface can be applied in the case of late sowing. It requires a temperature of 14-15 °C, pressing seeds to soil by rolling and immediate flooding with 3-5 cm water right after sowing is needed. Sowing into water is usually done by broadcasting from airplane. Seeds should be soaked for 24 hours then drained for 24-36 hours before aerial seeding. Fields must be drained immediately after seeding. Flooding up is performed slowly until tillering. The traditional way of cultivating rice from seedlings is not wide-spread in temperate zones.

Rice does not require deep water cover: wet soil at germinating, 3-5 cm increased up to 20 cm (upper third of the plant) for the second half of development. Final drainage can be started at the start of full ripening.

Upland rice technology (“dry rice”) was adapted to temperate conditions. Upland rice is grown in rainfed fields (rainfall 1,000-4,500 mm/year) at altitudes up to 2,000 metres. Upland rice varieties are adapted to poor soils, show improved blast resistance and drought tolerance. These can outyield traditional rices by more than 100%. Under temperate climate, upland rice is cultivated similarly to other small grain cereals with regular irrigation applied with a maximum rotation of one week.

Diseases

Bacterial blight (*Xanthomonas oryzae* pv. *oryzae* = *X. campestris* pv. *oryzae*), bacterial leaf streak (*Xanthomonas oryzae* pv. *oryzicola*), blast (leaf, neck [rotten neck], nodal and collar) (*Pyricularia grisea* = *P. oryzae*), eyespot (*Drechslera gigantea*)

Pests

Tadpole shrimp (*Triops cancriformis*), rice leaf miner (*Hydrellia griseola*), midgefly (*Cricotopus/Trichocladius bicinctus*), brown China mark (*Elophia nymphaeata*)

Harvesting

Drainage of rice fields must be started at the start of dough ripening and the fields must be dry till full ripening. Harvesting can be started if husk is yellow, seed is hard, seed

moisture is 20-25%. Desiccation can also be applied 5-7 days prior to harvesting. Seed must be dried to 14-15%. Grain yield is 2-5 t/ha.

2.1.10. Buckwheat and canary seed

Basic data of the cultivation of buckwheat and canary seed can be found in *Table 28*.

2.1.11. Test your knowledge

Describe the importance and quality of wheat/rye/triticale/barley/oat/maize/sorghums/millets/rice

Describe the botanical characteristics of wheat/rye/triticale/barley/oat/maize/sorghums/millets

Describe the environmental requirements of wheat/rye/triticale/barley/oat/maize/sorghums/millets/rice

Describe the main aspects of cultivation of wheat/rye/triticale/barley/oat/maize/sorghums/millets/rice

Give the sowing data of wheat/rye/triticale/barley/oat/maize/sorghums/millets/rice

List the diseases and pests of wheat/rye/triticale/barley/oat/maize/sorghums/millets/rice

Describe the harvesting and storage of wheat/rye/triticale/barley/oat/maize/sorghums/millets/rice

Table 28 Basic data of the cultivation of buckwheat and canary seed

	Buckwheat (<i>Fagopyrum esculentum</i> Moench.) 2n=16	Canary seed (<i>Phalaris canariensis</i> L.) 2n=12
Features		
	<ul style="list-style-type: none"> - food (husked grains, beer, etc.) and forage (grain and green forage); less importance as green forage (animals do not like it) - cover crop, green manure - bee pasture - contains high levels of: crude protein 18% (biological values above 90% - high concentration of essential amino acids), iron (60–100 ppm), zinc (20–30 ppm), selenium (20–50 ppm), antioxidants (rutin, tannins, etc.) - short season crop - prefers warm and humid conditions, from ripening it is frost-sensitive - does well on low-fertility or acidic soils if the soil is well drained - usually cultivated as second crop after winter barley, wheat and acts of nature 	<ul style="list-style-type: none"> - primarily utilized as bird seed - straw is forage - flour can be utilized for making bread and noodles, etc. - rarely, with legumes together it is produced as green forage - its grain has high protein content (20-25%) and beneficial composition of essential amino acids - prefers warm conditions, it is drought resistant - no special soil and forecrop preferences
Nutrient supply (kg/ha)		
N:	100	30-40
P ₂ O ₅ :	60	15-20
K ₂ O:	120-150	35-45
Data of sowing		
Date:	areas subjected to acts of nature: from 15. May second crop: 25. June – 15. July	20-30. March
Row distance:	seed: 24 cm green forage: 12 cm	24 cm
Sowing depth:	3-4 cm	2-3 cm
Seed rate:	seed: 2.5 million/ha or 60 seeds/m of row 60 kg/ha forage: 3.5 million/ha or 43 seeds/m of row 80 kg/ha	8-8.5 million/ha or 160-190 seeds/m of row 40-50 kg/ha
1000 seed weight:	20 g	7-8 g
Harvesting		
	<ul style="list-style-type: none"> - for green forage: harvesting ca. 30-40 days after seeding, at early flowering Yield: 15-20 t/ha - for grain: harvesting ca. 70-75 days after seeding; due to prolonged ripening desiccation is needed at the mid-ripening stage of grains in the middle side shoots, followed by harvesting in 3-4 days Yield: 0.8-1 t/ha 	<ul style="list-style-type: none"> - ripening in mid-summer - harvesting with the least yield loss if straw is bent below the panicle - harvesting with combine is usual Yield: 0.6-1.2 t/ha

2.2. PULSES

Pulses are leguminous species with seeds of relatively big size and high protein content. All of them belong to Fabaceae/Leguminosae.

2.2.1. Pea (*Pisum sativum* L.)

Pea is one of the oldest cultivated plants in the world, it was domesticated the same time as cereals. The growing area is 6,593,926.47 ha for dry and 2,266,368.61 ha for green pea. The global production is 9,830,015.66 tons for dry and 18,490,919.89 tons for green pea (FAO, 2012). For human consumption, the immature (green) peas (or the tender pod in snow peas) are used as a vegetable, fresh, frozen or canned, while varieties of field peas are grown to produce dry peas (green or yellow split pea shelled from the matured pod). Fodder pea (mostly varieties of *Pisum sativum* L. ssp. *arvense* /L./ POIR.) has a multipurpose use in livestock nutrition (green fodder, grain, silage etc.). However, compared to non-legumes, its yields are very variable and advancement in this field is very slow. Being high N-fixers, field peas produce abundant vining forage and contribute to short-term soil conditioning. Succulent stems break down easily and are a quick source of available N. Field peas grow rapidly in the cool, moist weather as winter annuals and as early-sown summer annuals.

Further benefits of field pea growing:

- Bountiful biomass. Under a long, cool, moist season during their vegetative stages, winter peas produce more than 5.8 t/ha dry matter, even when planted in spring in colder climates.
- Nitrogen source. As *Rhizobium* bacteria living in symbiosis with pulses are able to 'fix' nitrogen, field peas are top N producers, yielding from 100 to 170 kg N/ha, and at times up to 350 kg N/ha.
- Rotational effects. Pulse crops (grain legumes such as field peas, faba beans and lentils) improve sustainability of dryland crop rotations by providing disease suppression, better tillage and other enhancements to soil quality.
- Quick growing. Rapid spring growth helps peas out compete weeds and make an N contribution in time for summer cash crops in some areas.
- Forage booster. Field peas grown with barley, oat, triticale or wheat provide excellent livestock forage. Peas slightly improve forage yield, but significantly boost protein and relative feed value of small grain hay.
- Long-term bloomer. The purple and white blossoms of field peas are an early and extended source of nectar for honeybees.

Botanical characteristics

Field pea is an annual, cool-season, pulse crop. It has a taproot system of mediocre strength. There are two main types of field pea regarding growth habit. One type is an aggressive climbing variety and the other is a bush or dwarf type. Field pea stems grow from 60 to 100 cm (in the case of forage peas up to 150-200 cm) in length. Each leaf has a branched tendril at its tip and one to three pairs of leaflets. Most varieties of field pea produce white (*P.s.* ssp. *hortense*) (Figure 19) or reddish-purple (*P.s.* ssp. *arvense*) (Figure 20) flowers. Field pea stems (or vines) are prostrate at maturity. The pods contain from four to nine seeds and may be up to 8-10 cm in length.

Fodder pea grown for grain has high protein content (20-25%). The seed color is often green or yellow like at those produced for human consumption (*P.s.* ssp. *hortense*) but it can be dark brownish or mottled (*P.s.* ssp. *arvense*), too. The 1000 seed weight is 100-300 g.

Forage peas are usually leafy genotypes of high protein and carotene content. They have reddish-purple flowers, grains are usually colorful, purple or brownish (*P.s. ssp. arvense*). Seeds are usually smaller (1000 seed weight 70-120 g) than those of the yellow or green varieties.



Figure 19 Field pea



Figure 20 Fodder pea

Pea has several convarieties, the most important being:

- Round peas (*P. sativum* L. convar. *sativum*) – The surface of the ripe seeds is smooth (Figure 21 left). Seed coat can be easily removed (dehulling) thus split peas are produced. Round peas lose tenderness quickly. They are usually utilized after cooking. For other purposes harvesting at early stages of ripening is necessary.
- Wrinkled peas (*P. sativum* L. convar. *medullare* Alef.) – The surface of the ripe seeds is wrinkled (Figure 21 right). Wrinkled peas convert a low proportion of their sugar content into starch. The sugar level builds up inside the pea (6-9%, almost 100% sucrose), so they taste sweeter than the round ones. They cannot be dehulled. Wrinkled peas are utilized fresh, canned or deep-frozen.

- Snow peas (*P. sativum* L. convar. *axiphium* Alef.) – Their pods are free from parchment (hard endoderm), they feature flat pods that are sweet and edible (a.k.a. sugar peas). The seeds are very tiny, can be eaten fresh or cooked, traditional in stir-fry. They are called snap peas when they have plump and rounded edible pods instead of flat ones. It tends to be very sweet, and can be eaten raw or cooked.



Figure 21 Round (left) and wrinkled (right) peas

According to the extended BBCH-scale, pea has the following principal phenological growth stages:

- 0: Germination
- 1: Leaf development
- 3: Stem elongation (main shoot)
- 5: Inflorescence emergence
- 6: Flowering
- 7: Development of fruit
- 8: Ripening of fruit and seed
- 9: Senescence

The germination of pea is hypogeal (cotyledons remain below ground). Pea is a self-pollinating, long-day plant. Pods mature from the lowest flowering node upwards. At (over)ripening pea is prone to pod shattering and seed drop.

Its center of origin is Central Asia, the Near East, Abyssinia and the Mediterranean. Pea belongs to the family Fabaceae/Leguminosae and it is a diploid species ($2n=14$).

Pea is rich in protein (22-24%) and minerals. Carbohydrate content is 50-55%, fat content is 1.3-1.6%. It is rich in vitamins B₁, B₂ and C.

Environmental requirements

Peas are not heat-demanding crops. They germinate at 4.4 °C and at 2-3 leaves stage they tolerate some grades of frost. Overwintering forage peas are winter-hardy (-15-20 °C). The maximum temperature at vegetative growing is 12-14 °C, at flowering- ripening 18-20 °C. Pea has a moderate water requirement (200-250 mm), its transpiration coefficient being 300-500. It utilizes water relatively well but it is sensitive for drought at early stages of development and in the reproductive stage from flowering to pod set.

Peas are crops of the better wheat soils rich in lime (pH 6.5-8).

Cultivation

Its best and most common fore- and aftercrops are cereals. Other suitable forecrops are crucifers, flax and row crops fertilized with manure (e.g. potato, sugar beet). Rotation is 3-4 years. Pulses and legumes as well as other crops harvested late and leaving root and stem residues must be avoided as forecrops. Pea itself is an excellent forecrop for most non-relative crops. Tillage resembles those described for spring crops. Seedbed levelling is essential in order to reduce losses at harvesting. Basic fertilization and sowing data can be found in *Tables 29* and *30*, respectively. Among pulses peas have the highest demand for calcium. Irrigation is needed especially for green pea: 30-40 mm in rotation of 14 days.

Table 29 Nutrient requirement of pea

Nutrient uptake to 1 ton of grain and by-product					
dry pea	N: 60 kg/t	P ₂ O ₅ : 17 kg/t	K ₂ O: 35 kg/t	CaO: 32 kg/t	MgO: 6 kg/t
green pea	N: 19 kg/t	P ₂ O ₅ : 6 kg/t	K ₂ O: 15 kg/t	CaO: 10 kg/t	MgO: 2 kg/t
fodder pea	N: 35-45 kg/t	P ₂ O ₅ : 10-15 kg/t	K ₂ O: 15-25 kg/t	CaO: 10 kg/t	MgO: 2 kg/t

Table 30 Sowing data of fodder pea

Sowing date: - dry pea - green pea - autumn pea	25. February-31. March 25. February-10. April (in 10 day periods and/or with varieties of different growing period or based on effective heat units) 15-30. September
Row distance:	12-15.2 cm
Sowing depth:	5-8 cm
Seed rate: - grain (dry) - green	0.8-1 million seeds/ha (late to early varieties) 1.2-1.5 million seeds/ha (late to early varieties) yielding: 70-80% 150-300 kg/ha
1000 seed weight:	150-300 g

Diseases

Septoria leaf spot (*Septoria pisi*), *Sclerotinia* crown rot, *Fusarium* root rot as well as seed rot and blights of the stem, leaf or pod, *Ascochyta* blight (*Ascochyta pisi*), *Pseudomonas pisi*, *Sclerotinia minor*, *Sclerotinia trifoliorum*, PMV, PEMV

Pests

Heterodera goettingiana, *Otiorrhynchus ligustici*, *Sitonia* spp., pea aphid (*Acyrtosiphon pisum*), lima-bean pod borer (*Etiella zinckenella*), pea weevil (*Bruchus pisorum*)

Harvesting

Green peas

The most important quality aspect is tenderness. It is determined by finometer (F°), on the field and by tenderometer (T°), in the processing factory: $T^{\circ} = 3 \cdot (F^{\circ} - 3)$. Fresh pea loses tenderness quickly (3-5 F°/day, in case of threshed seeds even 1 F°/hour) thus it must be

delivered in the cold store in 4 hours. Optimal harvesting at 35-50 (45-50) F°. Too early harvesting results in the damage of seeds. Green pea is harvested by a pea harvester (pod stripper/combine). Its yield is 5-8 t/ha.

Dry and fodder peas

For grain food or feed, peas must be harvested by a specifically modified cereal combine at full ripening (16-18% moisture content) when leaves are dry, pods are yellow, seeds are hard. Combine must be equipped with a floating flexible cutter platform. If harvested by the indirect way (e.g. in the case of weedy fields or heterogenous ripening) cut plants are left on the field for post-ripening followed by threshing by a combine. Its grain yield is 3-5 t/ha.

For green forage or haylage, it can be mown at flowering according to the livestock's demand. Its green mass is 20-35 t/ha.

Field peas for hay should be harvested when most of the pods are well formed. Harvesting can be performed by using a mower with lifting guards and a windrow attachment to handle the sprawling vines.

2.2.2. Soybean (*Glycine max* /L./ Merr.)

Soybean is the fifth largest arable crop in the world regarding its growing area (104,997,252.85 ha). Its global production is 241,841,416.45 tons (FAO, 2012). Soybean provides vegetable protein for millions of people and ingredients for hundreds of chemical products, including paints, adhesives, fertilizers, insect sprays, and fire-extinguisher fluids. Because soybeans contain no starch, they are a good source of protein for diabetics. Processed for food, soybean oil is made into margarine, shortening, and vegetarian cheeses and meats. Soybean is considered to be a source of complete protein that contains significant amounts of all the essential amino acids (e.g. tryptophane, lysine, valine, leucine, tyrosine) that must be provided to the human body. It has a nutritional value similar to that of animal protein. Soybean meal serves as a high-protein meat substitute in many food products, including baby foods. Other food products include soybean milk, tofu, salad sprouts, and soy sauce.

Soy is extremely important as a relatively inexpensive source of protein and oil. Soy meal is the single most important animal feed in the EU, accounting for 55% of protein-rich animal feed. Soybean can be utilized in several ways as fodder (e.g. soybean meal, seed), green forage, hay as well as silage.

On ca. 75% of the total cultivation area GM soybean is produced. Most of the GM cultivars are herbicide tolerant and/or insect resistant but genotypes of modified oil composition are also commercially available.

Botanical characteristics

Soybean is a heat-demanding annual pulse crop. It has a deep root system. Soy varies in growth and habit. The height of the plant can be from below 20 up to 200 cm. The stems, leaves and pods are covered with fine brown or gray hairs. The leaves are trifoliate, having 3 to 4 leaflets per leaf, and the leaflets are 6–15 cm long. The leaves fall before the seeds are mature.

The inconspicuous, self-fertile flowers are borne in the axil of the leaf and are white, pink or purple. The fruit is a hairy pod that grows in clusters of 3–5, each pod is 3–8 cm long and usually contains 2–4 seeds 5–11 mm in diameter. Soybeans occur in various sizes, and

in many hull or seed coat colors, including black, brown, blue, yellow, green and mottled (Figure 22).



Figure 22 Soybean

According to the extended BBCH-scale, soybean has the following principal phenological growth stages:

- 0: Germination
- 1: Leaf development (main shoot)
- 2: Formation of side shoots
- 4: Development of harvestable vegetative plant parts (main shoot)
- 5: Inflorescence emergence
- 6: Flowering (main shoot)
- 7: Development of fruits and seeds
- 8: Ripening of fruits and seeds
- 9: Senescence

The germination of soybean is epigeous (cotyledons emerge above ground). Soybean is a self-pollinating, short-day plant. Soybean is less prone to pod shattering and seed drop compared to pea.

The center of origin of soybean is Northeast China and Manchuria. It belongs to the family Fabaceae/Leguminosae and it is a diploid species ($2n=40$).

Soybean has a high crude protein content of 40% (31.7-43.2%) and a high oil content of 20% (18.3-24.9%) which are in a strong negative correlation with each other ($r=-0.7$). Soybean oil is a major source of lecithin (2% of oil). Soybean is high in carotene, vitamin B, D and E. Soybean contains proteinase inhibitors such as the Kunitz- and Bowman-Birk-type trypsin and chymotrypsin inhibitors. These can be neutralized via extraction, as well as through hydrothermic, acidic, heat or microwave treatment.

Environmental requirements

Soybean is relatively resistant to low and very high temperatures but growth rates decrease above 35 °C and below 18 °C. Minimum temperatures for growth are about 10 °C and for crop production about 15 °C. Only 25 to 30% of the flowers set pods, the final number depending on the plant vigour during the flowering period. Year to year temperature variations can lead to differences in flowering. Soybean is basically a short-day plant, but response to daylength varies with variety and temperature and developed varieties are

adapted only to rather narrow latitude differences. The length of the total growing period is 100 to 130 days or more.

Soybean is a water-demanding crop, distribution of precipitation has determining role. Its transpiration coefficient is 750-800. Maximum of water requirement lasts from the beginning of flowering to the end of pod setting. Low water supply combined with high temperature can lead to the drop of flowers or fruits. From germination to budding and in the ripening stage soybean plants are relatively drought resistant.

Soybean can be grown on a wide range of soils except for those which are very sandy. Optimum soil pH is 6 to 6.5. A shallow water table, particularly during the early growth period can adversely affect yields. The plant is sensitive to waterlogging, but moderately tolerant to soil salinity.

Table 31 Nutrient requirement of soybean

Nutrient uptake to 1 ton of grain				
N: 62 kg/t	P ₂ O ₅ : 37 kg/t	K ₂ O: 51 kg/t	CaO: 42 kg/t	MgO: 9 kg/t

Cultivation

Best forecrops are small-grain cereals and maize. Besides pulses and leguminous crops, rapeseed, sunflower and other crops susceptible for *Septoria* infection should be avoided as forecrop. Rotation is 4 years. Basic fertilization and sowing data can be found in *Tables 31* and *32*, respectively.

Table 32 Sowing data of soybean

Sowing date:	15-30. April
Row distance:	45-50 (70) cm
Sowing depth:	3-5 cm
Seed rate:	
- very early (MG 00), early (MG 0)	650,000 seeds/ha
- middle late (MG I)	600,000 seeds/ha
- late (MG II)	550,000 seeds/ha
	30-35 seeds/m of row (45-50 cm)
	38-40 seeds/m of row (70 cm)
	70-150 kg/ha
1000 seed weight:	130-220 g

Seeds or soil must be treated with a *Bradirhizobium japonicum* concentrate right prior to sowing to improve N-fixation.

An efficient weed control has a decisive role in soybean yield.

Soybean is usually not grown under full irrigation. In certain climatic conditions, however, one or more supplemental irrigations during critical growth periods will increase yields. If one application is given, the best timing is in the late flowering period, when small pods are beginning to appear. If two applications are given, the first application is usually given at pre-emergence to assure a rapid establishment of the plant. A third application, where possible, will give the best results if given at the beginning of pod filling. Under dry continental climate, 2-3 x 40-50 mm doses between early June to mid-August (or even 2-4 x 50-60 mm, Σ 160-180mm) can be given.

Diseases

Downy mildew (*Peronospora manshurica*), Rhizoctonia stem rot (*Rhizoctonia solani*), Sclerotinia stem rot (*Sclerotinia sclerotiorum*), pod and stem blight (*Diaporthe phaseolorum* var. *sojae* and *Phomopsis longicola*), *Fusarium* spp., *Pseudomonas glycinae*, Soybean Mosaic Virus (SMV)

Pests

Ditylenchus dipsaci, *Acyrtosiphon onobrychis*, *Aphis fabae*, *Tetranychus urticae*, *Autographa gamma*, *Psolidium maxillosum*, *Sitona* spp., *Tanymecus* spp.

Harvesting

Soybeans are direct combined, preferably with a combine equipped with a floating flexible cutterbar and automatic header height control. Soybeans can be harvested at moisture levels below 20%, but they must be stored at 14% moisture or lower. Harvest losses and mechanical damage may be high when soybeans are harvested below 12% moisture. A floating cutterbar can be used to cut the soybean plants off, closer to ground level. Header maintenance is important. The majority of soybean losses occur at the header. Yield can vary widely with water availability, fertilization and row spacing. Under rainfed conditions, good soybean yields vary between 1.5 and 2.5 t/ha seed. High yields of improved varieties are between 2.5 and 3.5 ton/ha seed under irrigation.

Rough soybean seeds contain antinutritive compounds such as trypsin and lipase inhibitors. Both chemicals can be neutralized by various heat or chemical treatments in the course of seed processing.

2.2.3. Common bean (*Phaseolus vulgaris* L.)

Common bean (a.k.a. string bean, field bean, French bean, garden bean, etc.) is a food crop cultivated worldwide. Its dry or fresh seeds (shell beans) as well as the unripe fruits (snap beans utilized fresh, canned or deep-frozen) are used for human consumption. The leaves are occasionally used as vegetable, while the straw and other by-products of harvesting and processing (defected seeds, pod rests, etc.) can be used for fodder. Further benefits of common bean growing resemble those detailed for field pea regarding biomass, nitrogen source and rotational effects with the possibility for growing as second crop added.

Besides common bean (*Phaseolus vulgaris* L.), among others runner bean (*Ph. coccineus* L.), butter/lima bean (*Phaseolus lunatus* L.), mung bean (*Vigna radiata* Wilczek/*Ph. aureus* Roxb.) are also grown under temperate climate.

Botanical characteristics

The common bean is a highly variable species. According to the growth habit there are two basic types: bush varieties form erect, selfsupporting bushes of 20–60 cm (*Ph. vulgaris* L. convar. *nanus*), while pole/running varieties form vines of 2–3 m (*Phaseolus vulgaris* L. convar. *vulgaris/communis*). Beans have a relatively weak taproot system of 1–1.4 m depth. They have alternate leaves divided into three oval, smooth-edged leaflets, each being 6–15 cm long and 3–11 cm wide. The inflorescence is raceme of racemes. The papilionaceous flowers are white, pink, or purple. The pods are 5–25 cm long and 1–1.5(3) cm wide. These can be green or yellow (occasionally black or purple) in color, and contain 4–6(50) seeds (beans). The beans are smooth, plump, kidney-shaped, up to 1.5(3) cm long. They vary extremely widely in color (white, red, cream, black, brown, etc.), and are often mottled in two or more colors (*Figure 23*).



Figure 23 Common bean

According to the extended BBCH-scale, bean has the following principal phenological growth stages:

- 0: Germination
- 1: Leaf development
- 2: Formation of side shoots
- 5: Inflorescence emergence
- 6: Flowering
- 7: Development of fruit
- 8: Ripening of fruit and seed
- 9: Senescence

The germination of beans is epigeous. Common bean and lima bean are self-pollinated, while runner bean is cross-pollinated. Flowering happens from the lowest flower upwards (acropetal).

The center of origin of common bean is Central and South America (Soth Mexico, Bolivia, Peru). Common bean belongs to the family Fabaceae/Leguminosae and it is a diploid species ($2n=22$).

Bean is rich in protein (20-25%) with high lysine, cistine, tryptophan and histidine content. Carbohydrate content is 50-57%, oil content is 0.7-1.5%. It is rich in vitamins A, B₁, B₂, B₆ and E, as well as in iron, potassium, selenium and molybdenum.

Environmental requirements

Beans belong to the arable crops requiring the warmest conditions throughout their life cycle. It can be damaged already below 2 °C. Germination starts at 10-12 °C the optimum being 22-26 °C. For vegetative development 15-18 °C is preferred. In generative stage 20-24 °C is sufficient, the optimum being 24-28 °C. The bean species show high variability regarding the length of the growing period: *Ph. vulgaris* 80-140 days, *Ph. lunatus* 120-150 days, *Ph. coccineus* >140 days. Growing period of green beans can be extremely short: 50-80 days. Beans are daylength tolerant or short-day plants. They require a continuous water supply of appropriate level. The highest water requirement can be detected between budding/flowering and pod set. In the case of water scarcity accompanied with temperature above 26 °C, the abscission of flowers or developing pods can happen.

Beans prefer well-drained soils of loose structure which warm up quickly, are rich in lime (pH 6.5-8) and are in good general condition. Brown forest soils, cernozems, humic sand and alluvial soil are among the best, while compact meadow and loose sandy soils are of less importance. Cold, deep located soils, alkaline soils, eroded soils of shallow tilth should be avoided. Beans do not tolerate slack water and high salinity.

Cultivation

Its best forecrops are small grain cereals, potato, flax, hemp and sweet corn but maize, poppy and root vegetables are also accepted. If sown as second crop, early-harvested forage mixes, crimson clover, rapeseed, winter barley or green pea are preferred. Sunflower, tomato, bulb crops, weedy areas and areas with pesticide residues should be avoided. Rotation is 4-5 years. Tillage resembles those described for spring crops. If sown as second crop, shallow tillage (e.g. disc harrow or rotary tiller) and compacting (rollers) is necessary. Seedbed levelling is essential in order to reduce losses at harvesting. Basic fertilization and sowing data can be found in *Tables 33* and *34*, respectively. If cultivated by hand (e.g. pole beans), other planting systems such as twin-row or strip-sowing, planting in hills are also applied. In general, the effective ingredient doses are 40-70 kg/ha N, 45-75 kg/ha P and 60-100 kg/ha K. Bean is sensitive for scarcities in boron, molybdenum, zinc and copper. Inter-row cultivation is used to improve soil structure and as an alternative or supplement to chemical weed control by herbicides.

Table 33 Nutrient requirement of common bean

Nutrient uptake to 1 ton of grain and by-product					
dry bean	N: 55 kg/t	P ₂ O ₅ : 25 kg/t	K ₂ O: 40 kg/t	CaO: 38 kg/t	MgO: 8 kg/t
green bean	N: 13 kg/t	P ₂ O ₅ : 8 kg/t	K ₂ O: 12 kg/t	CaO: 13 kg/t	MgO: 3 kg/t

Table 34 Sowing data of common bean

Sowing date:	
- dry bean	5-15. May
- green bean	5. May-30. June (in ca. 5 sections, in 6-8 day periods; intermittence: 20. May-20. June)
- green bean (second crop)	1-20. July
Row distance:	
- dry	45 cm
- green	3 x 36 cm + 60 cm (strip sowing)
Sowing depth:	4-5 cm
Seed rate:	
- dry	(350)-500.000 seeds/ha
- green	450-600.000 seeds/ha established: 75-80% 150-300 kg/ha
1000 seed weight:	200-400 g

Dry bean is irrigated only in case of extreme drought. Green bean needs irrigation also to provide air humidity. Total amount of irrigation water is 100-150 mm if sown as primary

crop or 150-200 mm if cultivated as secondary crop. Prior to emergence 10-15 mm, from the canopy development to pod set 2-3 x 30-40 mm water is needed.

Diseases

Bean common mosaic virus (BCMV), bean common mosaic necrosis virus (BCMNV), bacterial brown spot and halo blight (*Pseudomonas syringae*), bacterial blight (*Xanthomonas campestris/axonopodis*), Alternaria leaf spot (*Alternaria alternata*), anthracnose (*Glomerella lindemuthiana*), black root rot (*Thielaviopsis basicola*), white mold/Sclerotinia rot (*Sclerotinia sclerotiorum*), Fusarium root rot (*Fusarium solani*)

Pests

Aphids (*Aphis craccivora*, *Acyrtosiphon pisum*), armyworms (*Spodoptera exigua*, *Spodoptera praefica*), corn earworm (*Helicoverpa armigera/zea*), cutworms (*Agrotis* spp.), leafminers (*Lyriomyza* spp.), loopers (e.g. *Trichoplusia ni*), seed corn maggot (*Delia platura*), broad nosed weevils (*Sitona* spp.), two-spotted spider mite (*Tetranychus urticae*), bean weevil (*Acanthoscelides obtectus*), stinkbugs

Harvesting

Green beans

For canning and freezing purposes harvest should be performed if pods ceased longitudinal growth, they are tender but firm and snap when they are bent, the seeds are immature and they do not form bumps on the pod. Beans are generally ready for harvest ca. 10-14 days after pod set. Green beans can be harvested by hand (in gardens, small area, pole beans) or by a green bean harvester. Its yield is 7-9 t/ha.

Dry beans

Dry beans are ready for harvest when leaves are yellow and majority of them has fallen, some of the pods are yellow, dry and wizened, beans are hard, they reached the size, shape and color typical for the genotype. Seed moisture content is 16-18(20)%. It is advised not to wait until all pods are fully ripened because too many dry pods at harvest can result in heavy shattering. Nearly mature dry beans in the yellow pods will continue to ripen after they are cut.

Straight combining is recommended only if the field is free of weeds and the crop ripens uniformly.

In the case of weediness and heterogeneous ripening, desiccation can be applied.

Other method for harvesting is undercutting and windrowing followed by combining from the windrow in ca. 1-2 days.

Shattering can be reduced if undercutting and windrowing are performed at night or early in the morning when the plants are damp with dew. To avoid seed discoloration, a harvest period relatively free from rain is required.

Dry bean yield is 1.2-2.5 t/ha. Storage is allowed at seed moisture of maximum 14%, following weevil control.

2.2.4. Lentil, chickpea, peanut, lupines and broad bean

Basic data of the cultivation of lentil, chickpea, peanut, lupines and broad bean can be found in *Tables 35* and *36*.

2.2.5. Test your knowledge

Describe the importance and quality of pea/soybean/common bean

Describe the botanical characteristics of pea/soybean/common bean

Describe the environmental requirements of pea/soybean/common bean

Describe the main aspects of cultivation of pea/soybean/common bean

Give the sowing data of pea/soybean/common bean

List the diseases and pests of pea/soybean/common bean

Describe the harvesting and storage of pea/soybean/common bean

Table 35 Basic data of the cultivation of some pulses

	Lentil (<i>Lens culinaris</i> MEDIK.) 2n=14	Chickpea (<i>Cicer arietinum</i> L.) 2n=16	Peanut/groundnut (<i>Arachis hypogea</i> L.) 2n=40
Features			
	<ul style="list-style-type: none"> - food crop of high nutritional value - contains high levels of: protein: 26-28%; fat: 1.5%; carbohydrates: 50-52%; essential amino acids: arginine, histidine; vitamins A, B₁, B₂; calcium, phosphorus, magnesium, iron - by-products (damaged seeds, straw, etc.) utilized as fodder - beneficial forecrop effects - extensive crop for sustainable farming - prefers moderate warm, humid climate - rotation of 3-4 years 	<ul style="list-style-type: none"> - food and fodder - contains high levels of: protein: 17-31%; fibre: 3.6%; fat: 6.1%; carbo-hydrates: 63.1%; essential amino acids: arginine, histidine; vitamins A, B, C; zinc, manganese, iron - remarkable agro-technical features: good forecrop, resistant to drought, lodging, shattering and seed weevils, the lower pods are relatively high above ground - extensive crop for the sustainable small-scale and eco-farming - prefers warm conditions 	<ul style="list-style-type: none"> - food crop (seeds, oil) of extremely high energy content - contains high levels of: protein: 28-34%; oil: 42-59%; vitamins B₁, B₂ - by-products (cake/meal, straw, etc.) utilized as fodder - prefers warm conditions and precipitation distributed evenly in the growing period - rotation of 3-4 years - needs hilling 2-3 times started from early flowering - irrigation is necessary in case of drought in the flowering stage
Nutrient supply (kg/ha)			
N:	(25-35) 40-60	50-60	40-50
P ₂ O ₅ :	(55-65) 60-70	60-80	60-80
K ₂ O:	(35-55) 80-100	100-120	120-150
Data of sowing			
Date:	1. March-20. March	15-31. March	25. April-10. May
Row distance:	(12) 24 cm	(12) 24 (36) cm	70 cm
Sowing depth:	3-5 cm	2-7 cm	5-6 cm
Seed rate:	2-2.5 million/ha 60-75/90-130 kg/ha	500,000/ha 100-150 kg/ha	200,000/ha 100 kg/ha
1000 seed weight:	25-35/50-80 g	200-300 g	400 g
Harvesting			
	<ul style="list-style-type: none"> - harvest prior to full ripening; yellowish brown pods with hard seeds on the middle and lower parts of stem - separate cutting, windrowing and threshing is preferred - dessiccation can be applied Yield: 1-1.2 t/ha 	<ul style="list-style-type: none"> - ripe: leaves are dry, pods are yellow and dry, seeds are dry and they rattle - harvesting with combine is usual Yield: 0.8-1.2 t/ha 	<ul style="list-style-type: none"> - ripe: bushes fall apart, leaves are yellow, pods are bone-white and hard, inside white, seeds reach color and size characteristic for the genotype - harvest by hand or special harvesters (e.g. modified plows) - post-harvest drying of bushes upside down Yield: 1.2-1.5 t/ha Seed:pod = 75:25%

Table 36 Basic data of the cultivation of some pulses (continued)

	White lupine (<i>Lupinus albus</i> L.) 2n=50	Yellow lupine (<i>L. luteus</i> L.) 2n=52	Blue lupine (<i>L. angustifolius</i> L.) 2n=40	Broad bean (<i>Vicia faba</i> L.) 2n=12
Features				
	<ul style="list-style-type: none"> - bitter lupins: high (1-3%) alkaloid (in yellow: lupinine, lupinidine; in white and blue: lupanine, hidroxilupanine, D-lupanine) content causes toxication; for green manure or feeding fish - sweet lupins: low (<0.1%) alkaloid content; for feed (grain, green, silage, etc.) and food - contain high levels of: protein: 35-39%; essential amino acids: lysine, methionine, cysteine; fibres: 12%; oil: 9%; vitamins A and B; iron, magnesium, phosphorus, potassium, sodium - amino acid composition resembles that of egg protein, has excellent digestibility - prefer acidic sandy soils, white requires soils of better quality (less lime sensitivity) - rotation of 4-5 years 		<ul style="list-style-type: none"> - food and fodder (grain, green, silage, etc.) - contains high levels of: protein: 29-32%; vitamins A, B₁, B₂, C; iron, magnesium, phosphorus, potassium, sodium - contains very low levels of antinutritive substances - problem: low level of ecological plasticity - prefers cool and humid climate - irrigation in the case of drought 	
Nutrient supply (kg/ha)				
N:	17-34		30-60	
P ₂ O ₅ :	18-36		40-80	
K ₂ O:	60-100		150-170	
Data of sowing				
Main crop:	20. March-5. April	15-30. March	15-25. March	10-25. March
Second crop:	1-15. July	1-15. July	10-15. July	
Row distance:	24 (36) cm	12 cm		24 (36) cm
Sowing depth:	3-4 cm	2-3 cm	3-4 cm	6-10 cm
Seed rate:	380-420,000/ha 120-130 kg/ha	800-900,000/ha 120-140 kg/ha		500-600,000/ha 300-500 kg/ha
1000 seed weight:	280-330 g	120-160 g	90-130 g	250-800 g
Harvesting				
	<ul style="list-style-type: none"> - for green manure plowing at the end of full flowering – pod set - for green forage harvest at budding – early flowering stage - ripe: stem is hard, ligneous, leaves fallen, pods do not break and shatter, seed moisture 14-16% (ripening in August) or 18-20% (ripening in September) - yellow lupine: seeds can shatter, harvest before full ripening - white lupine: shattering is less probable, harvest at full ripening - harvest by combine Yield: 0.8-1.8 t/ha 		<ul style="list-style-type: none"> - ripe: 90% of pods is black, seeds are hard, seed moisture content is 16-18% - ripening tends to be uneven and prolonged - in the case of extremely prolonged ripening and/or weedy population desiccation can be applied - harvest by combine, leaving high stubble Yield: 1.2-1.9 t/ha 	

2.3. ROOTS AND TUBERS

2.3.1. Potato (*Solanum tuberosum* L.)

Potato is the world's fourth-largest food crop, following maize, wheat and rice. The growing area is 19,202,081.65 ha, the global production is 364,808,768.31 tons (FAO, 2012). Potato is staple food in various forms such as pommes frites, chips, puree, flour, salad, etc. In industry potato is used as the source of starch, spirit, sugar. It has importance as forage, too.

Potato is rich in starch (12-14%, up to 23%), vitamin C (20-25 mg/100 g) and potassium (1700-2000 mg% in d.m.). It has low protein content (1-2%). The toxic solanine is usually produced in tuber exposed to sunshine.

Table 37 The EAPR (European Association for Potato Research) classification of potato varieties according to their cooking behavior

Cooking type	Description
A	particularly firm, non-mealy potato with a fine structure; for salads
B	firm, slightly mealy potato with a fine or rather fine structure; for mixed utilization, pommes frites
C	rather loose, mealy potato; for puree flakes, pasta raw material, chips
D	loose, very mealy potato; for puree flakes

Botanical characteristics

Potato has an adventitious root system arising from the base of a sprout. Root growth is usually restricted to the top soil layer of 20-30 cm depth. Potato stem is stout, erect, flexuous, much branched, slightly hairy, 30-60 cm long. The main stem arises from the first and high order buds. Branches arise from below ground nodes on the main stem. Underground stems are called stolon the end of which may form a tuber. Potato leaf is composed of two to four pairs of primary leaflets arranged on the mid-rib with a terminal leaflet on the end. Between the primary leaflets secondary and tertiary leaflets can be present. The leaf is attached to the plant by a petiole. The inflorescence is a scorpioid cyme born on the apex. The color of flowers is from white to dark lilac depending on genotype (*Figure 24*). Potato fruit is a berry.



Figure 24 Potato

The vegetative propagating organ of potato, the tuber is a thickened modified stem having cells filled with starch. The end of the tuber which joins the stolon is called the stem end, the other end where the eyes are clustered is known as the bud or apical end. Tuber skin colour may be red, pink or blue, purple or white or yellow. Flesh colours may be white, creamy white, creamy yellow or yellow. Skin and flesh color does not have any relation with potato quality (*Table 37*).

According to the extended BBCH-scale, potato has the following principal phenological growth stages:

- 0: Sprouting/Germination
- 1: Leaf development
- 2: Formation of basal side shoots below and above soil surface (main stem)
- 3: Main stem elongation (crop cover)
- 4: Tuber formation
- 5: Inflorescence (cyme) emergence
- 6: Flowering
- 7: Development of fruit
- 8: Ripening of fruit and seed
- 9: Senescence

Tuber initiation (40) is approximately parallel with the inflorescence emergence (51).

The centers of origin of potato are upland areas of Chile, southern Peru, northwestern Bolivia and Ecuador. Potato belongs to the family Solanaceae. It is a tetraploid species ($2n=48$).

Environmental requirements

Potato is a temperate climate crop, however it grows under a diverse range of climatic conditions. Depending on genotype, its growing period is 85-125 days long. It prefers moderately cool temperature during the growing season (effective heat unit: 1300-1500 °C). Sprouting starts at 6-8 °C. It withstands frost to -1.5 °C. Potatoes are sensitive to heavy frosts, which damage them in the ground. Even cold weather makes potatoes more susceptible to bruising and possibly later rotting, which can quickly ruin a large stored crop. The vegetative growth of the plant is best at a temperature of 21-24 °C, while tuber development is favoured at 17-20 °C. For the optimal development of tubers a significant difference between day and night temperatures is essential. Potato has a moderate (500-600 m) but continuous water requirement. The maximum need is during flowering parallel with tuber development (300-350 mm). During ripening and harvesting dry and warm weather is preferred. While flowering requires long days, tuberization of potato is induced by short days and prevented by long days. Different genotypes, however, probably have different requirements and temperature can also influence the effect of daylength.

Potato can be grown on a wide range of soils. Naturally loose soils offering least resistance to the enlargement of the tubers are preferred. Loamy and sandy loam soils, rich in organic matter with good drainage and aeration, free of chemical residues and rhizomatous perennial weeds are most suitable for cultivation of potato crop. The soil with pH range of (4.5)5.2-6.4(7.5) is considered to be ideal. Compact, cold, eroded, saline and alkaline soils must be avoided.

Cultivation

Potato has special requirements for forecrops. The best are small-grain cereals, rapeseed, pulses, white mustard and oilseed raddish. Green manure plants such as oilseed raddish, yellow lupin (on acidic sand), sweet clover (on alkaline sand). Following forecrops must

be avoided: late harvested crops of high water consumption (maize, sorghum, foxtail millet); crops leaving much stem residues (sunflower); weediness (alfalfa); Solanaceae species (tomato, pepper, tobacco, eggplant); lupins grown for seed, vegetables, herbs and spices leaving much root residues. Rotation must be 3 years on loose and 4 years on medium-compact soils. Potato can be followed rye, winter barley, wheat and spring crops, while sugar beet, sunflower, tomato and lupins must be avoided.

Potato requires an appropriately prepared soil and seed bed. Following stubble cleaning, primary tillage can be performed by autumn or spring (on extreme loose sand) mouldboard or chisel plowing at 20-25 cm followed by spring secondary tillage at 15-18 cm (12-15 cm for early potato). Potato can be planted also into pre-formed beds which are established by using either a mulching machine or a lister and bed shaper. After establishing the beds, a chisel is run into the center of the bed to ca. 45 cm. An advantage of this practice is breaking up plow soles, which results in better water drainage and soil aeration.

Basic fertilization and sowing data can be found in *Tables 38 and 39*, respectively. In general, the effective ingredient doses are 150-200 kg/ha N, 60-80 kg/ha P and 180-240 kg/ha K. Potato is a chloride-sensitive crop thus the widely used potassium-chloride should be avoided. Potassium-sulphate can be applied as basic fertilizer while potassium-nitrate for topdressing. Farmyard and green manures have beneficial effect on growing and quality.

Seed potato can be round-oval (cross-diameter: 28-45/45-60 mm) or long (25-35/35-45 mm) and 45-150 g. Seed potato of smaller size result in tubers of bigger size. Higher number of primary shoots per m² results in tubers of smaller size. Tubers cut into small pieces containing minimum 2 eyes can also be used for planting after suberization.



Figure 25 Chitted potato seed

Potato seeds need to be chitted (sprouting the tubers) prior to planting early potato. It is performed by putting tubers, most eyes upright, in a light (60-100 lux), cool but frost-free place at about 12-18 °C. Strong, short green shoots of 1.5-2 cm develop in 2-4 weeks (*Figure 25*).

Table 38 Nutrient requirement of potato

Nutrient uptake to 1 ton of grain				
N: 5 kg/t	P ₂ O ₅ : 2 kg/t	K ₂ O: 9 kg/t	CaO: 3 kg/t	MgO: 1 kg/t

Hilling (earthing up, ridging) is an essential activity in potato crop care. This may encourage the development of additional tubers preventing tubers growing just below the surface from producing chlorophyll and toxic solanine if exposed to light (green potatoes). Primary ridge is prepared at planting and it has a height of 8-12 cm above seed tuber. Secondary (final) ridge is prepared 2-4 days prior to emergence or by earthing up after emergence, before blooming (15-20 cm plant height). A good ridge has triangular shape with a height of 24-30 cm above furrow and a bottom of 45-50 cm width. Planting in pre-prepared ridges is also applied. Early potato needs ridges of smaller volume. If early potato is grown without cover, hilling at planting and prior to emergence should be avoided due to resulting in delayed ripening.

Inter-row cultivation is used to improve soil structure and as an alternative or supplement to chemical weed control by herbicides.

Potato is usually irrigated from the start of tuber set (budding) to 7-10 days prior to full development of tubers. Irrigation must be applied to the needs of potato thus little doses applied regularly are preferred. First dose is 40-60 mm followed by 3-4 x 30-50 mm doses (12-14 or 14-18 days of rotation on loose or medium-compact soils, respectively). In the case of drought rotation can be 1-5 days.

Table 39 Sowing data of potato

Sowing date: - traditional - early - summer	(late March) 15-25. April 10-15. March (without cover) late June – early-mid July
Row distance:	70-75 cm
Sowing depth:	1-4 cm
Seed rate: - commercial • traditional, summer • early - seed potato	42,000-50,000 seeds/ha (with elite, „small” seed tubers: 55-60,000 seeds/ha) 50,000-60,000 seeds/ha 60,000-75,000 seeds/ha 1.9-4.3 t/ha

Diseases

Viruses: potato leafroll virus (PLRV), potato virus Y (PVY), PVA, PVM, PVX, PVS, PAMV, TNV, TRV, PMTV

Bacterial diseases: common scab (*Streptomyces sp.*), bacterial soft rot or blackleg (*Erwinia sp.*), bacterial wilt (*Ralstonia solanacearum*), ring rot (*Corynebacterium sepedonicum*)

Fungal diseases: Fusarium dry rot, Fusarium wilt (*Fusarium spp.*), late blight (*Phytophthora infestans*), Rhizoctonia canker and black scurf (*Rhizoctonia solani*), early blight (*Alternaria solani*), silver scurf (*Helminthosporium atrovirens*), gangrene (*Phoma foveata*)

Phytoplasmal diseases: potato stolbur phytoplasma, witches' broom phytoplasma, aster yellows group of phytoplasmas

Viroid diseases: potato spindle tuber viroid (PSTV)

Pests

Colorado potato beetle (*Leptinotarsa decemlineata*), blister beetles, flea beetles (*Epitrix* spp.), potato leafhopper (*Empoasca fabae*), aphids (*Myzus persicae*, *Macrosiphum euphorbiae*; virus vectors!), wireworms, white grubs

Physiological disorders

aerial tubers, air crack, air pollution injury, black heart, blackspot bruise, deformation, elephant hide, greening, hollow heart, internal brown spot = heat necrosis, jelly end rot, physiological leaf roll, psyllid yellows, shatter bruise, skinning, stem-end browning, swollen lenticels

Harvesting

Potato is ripe and ready to be harvested when leaves and stem are dead, stems are bleached and dry, maximum of total tuber mass is reached, and tubers detach easily from stolons. Skin set is complete (skin at apical end of tuber not removable with thumb). Early („new”) potatoes are harvested when skin set is not yet complete (skin easily removable with thumb) and they reach a diameter of ca. 2.5 cm.

Harvesting needs dry and rugged conditions. Harvesting must be avoided when pulp or internal temperatures of the tubers are below 8 °C or above 18 °C. Harvesting at low temperatures leads to bruising, while crops harvested at high temperatures are prone to tuber breakdown from bacterial soft rot and pythium.

Long-term storage potential of potato can be increased by ensuring proper skin set on the tuber prior to harvest. Thickening of skin on maturation can be accelerated by topkilling the crop when the tubers reach the desired size. Topkilling involves spraying the crop with desiccants, or by flailing (mechanical removal of potato tops).

Potatoes are lifted with a potato digger and then picked by hand, or harvested with a potato harvester.

Potato can be stored under various conditions, such as clamps, storage boxes, containers, etc.

Storage steps are the following:

1. Drying: max. 1-2 weeks
2. Curing/suberization (healing wounds occurring during harvest): 12-15 °C, 92% air humidity, 10-14 days
3. Cooling down tubers: slow (0,5 °C/day), 20-40 days, aeration is necessary
4. Main storage period: innate or endodormancy as well as imposed or ecodormancy
seed (and table) potatoes 2-4 °C, table potatoes 4-7 °C, french fry potatoes 5-8 °C,
chips potatoes 7-12 °C
Aeration: 6-12 hours/week
Storage losses are caused by respiration, evaporation, sprouting and rot.
5. Warming up (prior to utilization) to 10 °C, <2 °C/day

2.3.2. Sugar beet (*Beta vulgaris* L.)

Sugar beet is one of the youngest cultivated plants. Its selective breeding from the 'White Silesian' fodder beet was started by Franz Karl Achard in 1784, based on the discovery of the existence of a sugar in vegetables similar to that obtained from sugarcane by Andreas Sigismund Marggraf in 1747. By the beginning of the 19th century, sugar beet contained ca. 5-6% sucrose. Achard opened the world's first beet sugar factory in 1801, at Cunern in

Silesia. The growing area of sugar beet is now 4,900,845.40 ha, the global production is 269,865,481.00 tons (FAO, 2012).

Sugar beet has a raw sugar (sucrose) content of 14-18% (up to ca. 23%). White sugar content is ca. 80% of raw sugar content. Amino-nitrogen decreases the amount of sugar extracted, it should be 20-50 mg/100g root. High concentrations of potassium and sodium in soluble ash (above 0.5-0.6%) can hinder the crystallization of sugar. It takes about 9 sugar beets to make 1 kg of sugar. This corresponds to an area under cultivation of about 1 square metre.

Sugar beet is primarily used for the production of white crystallized sugar (sucrose) and its derivatives such as brown sugar, powdered sugar, beverages and bioethanol or biobutanol. By-products of harvesting (crown and head) and processing (wet or dried/pressed pulp or cossettes, as well as molasses) can be used as livestock fodder supplement. Other utilization of crown and head is as green manure, while molasses is used in the production of spirits, sugar-syrup, substitution of honey, as well as in the treatment of road surfaces.



Figure 26 Cross section of sugar beet (left and right) and fodder beet (centre) roots

Botanical characteristics

Sugar beet is a biennial plant. It consists of four parts: leaves, head, neck and root. In the first year (vegetative stage), it has three types of leaves (A, B and C type) emerging successively. The head (epicotyl) and leaves are also called tops or haulm. The neck (hypocotyl) contains neither leaves nor lateral roots. The root is a taproot, the shape of which is conical, turnip-like, whitish to light yellow in color. It has two longitudinal bud furrows on opposite sides. Its tail-like end ($\varnothing < 1$ cm) usually breaks off when the root is harvested. The number of the concentric rings of vascular tissue alternating with storage parenchyma is 9-12 in sugar beet (*Figure 26*). The angular flowering stalk elongates (bolts) from the root in the second growing season (reproductive stage), it grows ca. 1.2-1.8 metres tall. At the base of the stem large petiolate leaf develops, further up the stem there are less petiolate, finally sessile leaves developing. Secondary shoots forming a series of indeterminate racemes develop at the leaf axils. Flowers are small, sessile and occur singly or in clusters. Multigerm beet fruit is formed by an aggregation of two or more flowers. It is a cluster of nutlets enclosed within the swollen corky perianth-bases (*Figure 27*). Genetically monogerm (monocarp) fruits or monogerm fruits produced by the

segmentation of the multigerm ones are widely used in growing. Sugar beet belongs to the family Chenopodiaceae and diploid genotypes have $2n=18$ chromosomes.

Diploid (occasionally triploid) hybrids of sugar beet are cultivated worldwide. Hybrids can possess the following resistance traits:

- Cr: *Cercospora* resistant
- Rt (Rz): *Rhizomania* tolerant
- Rt (Rz) + Cr: *Rhizomania* tolerant and *Cercospora* resistant
- Rt (Rz) + Me: *Rhizomania* tolerant and powdery mildew resistant
- Rt (Rz) + Rc: *Rhizomania* tolerant and *Rhizoctonia* resistant

According to the extended BBCH-scale, sugar beet has the following principal phenological growth stages:

- 0: Germination
- 1: Leaf development (youth stage)
- 3: Rosette growth (crop cover)
- 4: Development of harvestable vegetative plant parts (beet root)
- 5: Inflorescence emergence (2nd year of growth)
- 6: Flowering
- 7: Development of fruit
- 8: Ripening
- 9: Senescence

Sugar beet is cross-pollinated.



Figure 27 Sugar beet

Environmental requirements

Sugarbeet is a temperate zone crop. The growing period is 170-200 days long. It prefers moderately warm temperature during the growing season (effective heat unit: 2400-2600 °C). Sugar beet requires 460-600 mm of rainfall to raise an average crop. Most of the water is needed during the stage of intensive tuber development. Sunshine of long duration but not of great intensity is an important factor in the successful cultivation of sugar beets.

Sugar beet germinates at 4 °C (15-20 days). Until leaf canopy completely covers soil surface, sugar beet requires gradually increasing temperature (10-12 °C) and moderate precipitation. In the stage of root and leaf development, a temperature ranging from 15 to

21 °C is most favorable. For sugar accumulation in the last part of first year development moderate warm days (up to 17 °C) and cool nights (ca. 12 °C) are essential. Frost tolerance is -2-3 °C in the early, while -5-7 °C in the late stages of development.

Sugar beet has the highest requirements for soil. The soil must be of homogenous structure, have a deep tilth, contain a large supply of nutrients, be rich in humus, have the property of retaining a great deal of moisture. It has a pH optimum of 6.5-7.3. Generous crops are grown in sandy soil as well as in heavy loams, while the ideal soil is a sandy loam. Chernozems, brown forest soils and meliorated meadow soils are among the best ones. Eroded, rocky, heterogenous, gritty soils, shifting sand, shallow tilth, weedy areas should be avoided.

Cultivation

Sugarbeet has special requirements for forecrops. It must be harvested in the summer, must not leave much residual nitrogen, require potassium, leave herbicide residues. The best are small-grain cereals, especially winter wheat and barley. Rotation is 4 years to avoid sugarbeet nematode (*Heterodera schachtii*) contamination. Sugarbeet can be followed e.g. by spring barley, winter wheat, maize, peas and hemp.

Sugar beet requires deeply cultivated, sufficiently settled soil with a compact base and a friable, crumbly structured upper layer. Fall tillage should match to soil type, previous crop residue present, and be compatible with soil conservation requirements. Moldboard and chisel plows, disks and field cultivators all can be successfully used for primary fall tillage. Deep plowing of 32-36 cm or subsoiling at 40-50 cm, possibly combined with ploughing are usually applied. Spring tillage should be kept to a minimum. It must preserve seedbed moisture and reduce the chance of wind damage to weak sugarbeet seedlings as they emerge. The seedbed should be level, shallow and firm to allow good seed to soil contact. Common tillage tools are light harrows, multiweeders, and combination Danish tine, harrow, rolling basket tillage tool systems. Seedbed must be prepared ca. 5 cm deep. Planting should follow spring tillage as quickly as possible (ca. 24 hours) to prevent seedbed drying. Sugarbeets have been successfully planted with no-till, with strip tillage in previous crop residues, and other reduced tillage systems, too.

Table 40 Nutrient requirement of sugar beet

Nutrient uptake to 1 ton of grain				
N: 20-30 kg/t	P ₂ O ₅ : 15-20 kg/t	K ₂ O: 30-50 kg/t	CaO: 10-15 kg/t	MgO: 8-10 kg/t

Table 41 Sowing data of sugar beet

Sowing date:	15. March-10. April
Row distance:	45 cm
Sowing depth:	3-4 cm
Seed rate (U=100.000 germs):	
- on site (plant distance 15-16 cm)	1.4-1.6 U/ha
- loose (plant distance 10-14 cm)	1.8-2.6 U/ha
- dense (plant distance 4-6 cm)	1.8-4.5 U/ha
Yielding plant:	
- irrigated	80,000-90,000/ha
- non-irrigated	100,000-120,000/ha

Basic fertilization and sowing data can be found in *Tables 40* and *41*, respectively. In general, the effective ingredient doses are 80-120 (120-160) kg/ha N, 100-120 kg/ha P and 150-180 (180-210) kg/ha K. Sugarbeet has a special boron, zinc, iron and copper requirement. Sugarbeet is planted with precision row crop planters. Sugarbeets may be planted to thin to a final stand (dense, loose) or space planted to a desired final plant population. Fruits are polished, seeds are pelleted and coated prior to sowing.

If thinning is necessary, it must be performed at the stage of 5-6 leaves.

Inter-row cultivation is used to improve soil structure and as an alternative or supplement to chemical weed control by herbicides.

Irrigation is essential in areas with very low rainfall but should not be started prior to the developmental stage of 4-6 leaves. Doses of 40-80 mm water must be applied 4 times during the root development stage.

Diseases

Virus diseases

Rhizomania (beet necrotic yellow vein virus), beet western yellows virus, beet mosaic virus, beet curly top virus

Bacterial diseases

Agrobacterium tumefaciens, beet vascular necrosis and rot (*Erwinia carotovora*), bacterial leaf spot or leaf blight (*Pseudomonas syringae*)

Fungal diseases

Aphanomyce root rot and black root (*Aphanomyces cochlioides*), Phytophthora root rot (*Phytophthora drechsleri*), Pythium root rot (*Pythium aphanidermatum*), Rhizoctonia root and crown rot (*Rhizoctonia solani*), Rhizopus root rot (*Rhizopus stolonifer*, *R. arrhizus*), Fusarium root rot (*Fusarium oxysporum* f.sp. *radicis-betae*), Cercospora leaf spot (*Cercospora beticola*), powdery mildew (*Erysiphe polygoni*), Alternaria leaf spot (*Alternaria alternata*), Phoma leaf spot (*Phoma betae*), Verticillium wilt (*Verticillium alboatrum*)

Phytoplasma disease

Syndrom des basses richesses

Pests

Flea beetle (*Chaetocnema concinna*), peach-potato aphid (*Myzus persicae*), black bean aphid (*Aphis fabae*), beet leaf miner (*Pegomya hyoscyami*), cutworm (*Agrotis segetum*), beet leafhopper (*Circulifer tenellus*), sugarbeet weevil (*Cleonus punctiventris*), sugarbeet leaf weevil (*Lixus scabricollis*), nematodes, cutworms

Harvesting

Sugarbeets reach biological ripening if sugar produced is equal with sugar utilized by respiration. It means a raw sugar content of 16-18%. Sugarbeets are harvested in the autumn, from September to October or November. It needs a specialized set of machines. Currently topper/harvesters operating in one round are applied most frequently. Foliage is removed from the beet root by a mechanical defoliator prior to lifting. It can also be performed by cutting the beet head. Immediately following defoliation, sugarbeet lifter-loader harvesters pull beets from the soil and load them on trucks. The harvesters remove most of the soil from the beets prior to loading them on trucks.

2.3.3. Test your knowledge

- Describe the importance and quality of potato/sugarbeet
- Describe the botanical characteristics of potato/sugarbeet
- Describe the environmental requirements of potato/sugarbeet
- Describe the main aspects of cultivation of potato/sugarbeet
- Give the sowing data of potato/sugarbeet
- List the diseases and pests of potato/sugarbeet
- Describe the harvesting and storage of potato/sugarbeet

2.4. OILSEED CROPS

Seed oil of oilseed crops contains various fatty acids that determine the characteristics and utility of the oil. The iodine number measures the degree of unsaturation in oils, and shows the amount of iodine in grams that is taken up by 100 g oil.

Characterization of oils according to the iodine number:

- drying oils: iodine number >130
 - semi-drying oils: iodine number 85-130
 - non-drying oils: iodine number <85
- (to compare, pig fat: iodine number 60-70)

Table 42 Fatty acid composition of some common edible fats and oils

Fatty acid composition of some common edible fats and oils.									
Oil or Fat	Unsat./Sat. ratio	Saturated					Mono unsaturated	Poly unsaturated	
		Capric Acid	Lauric Acid	Myristic Acid	Palmitic Acid	Stearic Acid	Oleic Acid	Linoleic Acid (ω6)	Alpha Linolenic Acid (ω3)
		C10:0	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	C18:3
Beef Tallow	0.9	-	-	3	24	19	43	3	1
Butterfat (cow)	0.5	3	3	11	27	12	29	2	1
Butterfat (human)	1.0	2	5	8	25	8	35	9	1
Canola Oil	15.7	-	-	-	4	2	62	22	10
Cocoa Butter	0.6	-	-	-	25	38	32	3	-
Cod Liver Oil	2.9	-	-	8	17	-	22	5	-
Coconut Oil	0.1	6	47	18	9	3	6	2	-
Corn Oil (Maize Oil)	6.7	-	-	-	11	2	28	58	1
Cottonseed Oil	2.8	-	-	1	22	3	19	54	1
Flaxseed Oil	9.0	-	-	-	3	7	21	16	53
Grape seed Oil	7.3	-	-	-	8	4	15	73	-
Lard (Pork fat)	1.2	-	-	2	26	14	44	10	-
Olive Oil	4.6	-	-	-	13	3	71	10	1
Palm Oil	1.0	-	-	1	45	4	40	10	-
Palm Kernel Oil	0.2	4	48	16	8	3	15	2	-
Peanut Oil	4.0	-	-	-	11	2	48	32	-
Safflower Oil	10.1	-	-	-	7	2	13	78	-
Sesame Oil	6.6	-	-	-	9	4	41	45	-
Soybean Oil	5.7	-	-	-	11	4	24	54	7
Sunflower Oil	7.3	-	-	-	7	5	19	68	1
Walnut Oil	5.3	-	-	-	11	5	28	51	5

Percentages may not add to 100% due to rounding and other constituents not listed.

Source: <http://oilpalmblog.wordpress.com/2014/01/25/1-composition-of-palm-oil/>

Oilseed crops can be sorted according to the drying ability of their oil:

- Oleic acid (18:1) group: non-drying oil; olive, peanut, coriander. Iodine number: 80-110
- Linoleic acid (18:2) group: semi-drying oil. soybean, sunflower, cotton, tobacco, poppyseed, maize germ, safflower, pumpkin. Iodine number: 100-150
- Linolenic acid (18:3) group: drying oil. linseed, hemp, sesamseed, perilla. Iodine number: 140-210
- Erucic acid (22:1) group: non- or hardly drying oil. rapeseed, black mustard. Iodine number: 90-110
- Oxyacid group: non-drying oil. castor oil plant. Iodine number: 80-90.

Fatty acid composition of some common edible fats and oils are shown in *Table 42*.

The production of vegetable oils in the world is shown in *Table 43*.

Table 43 World production of vegetable oils (FAO, 2012)

Oil	Oil production (tons)
Palm	50,169,708.00
Soybean	41,205,379.44
Rapeseed	22,254,970.69
Sunflower	15,215,301.03
Palm kernel	6,065,314.22
Peanut	5,242,362.56
Cottonseed	5,271,972.13
Coconut (copra)	3,310,133.86
Olive, virgin	2,903,676.42
Maize	2,378,584.03
Sesame	1,201,610.02
Linseed	540,474.71
Safflower	154,045.63
Total:	155,913,532.74

2.4.1. Sunflower (*Helianthus annuus* L.)

Sunflower is one of the most important oilseed crops in the temperate zone. Its growing area is 24,843,104.00 ha, the global production is 37,449,403.00 tons (FAO, 2012). Sunflower oil is used by food industry (cooking oil, margarine, etc.), cosmetic industry (creams, etc.), textile industry, soap, paint, plastic production. It is a valuable raw material of biodiesel production. By-products of oil-extraction (sunflower meal of 34-46%, cake of 48-50% protein) are food for livestock (especially for ruminants). Sunflower seed is used for human consumption (raw, baked, roasted, salted or not salted) or as birds' food. Hulls are used for the production of fodder starch and furfural, as well as biomass for energy production. The plant produces latex to be used as nonallergenic rubber, the fibres of the stem can be used in paper production. The whole plant can be utilized as green forage and silage (protein content of silage: 14-16%). Sunflower can be used as green manure as well as for phytoremediation. It is a valuable honey plant (20-30 kg honey/ha) and some genotypes are used as ornamental plants.

High oil sunflower contains 46-54% (up to 57-59%), while confectionary genotypes 32-38% oil. The oil is of high nutritional value (due to high linoleic acid content), as well as stable with good storage life (due to lack of linolenic acid). Oil of high-oleic (HO) genotypes contains ca. 82% oleic acid. This type of oil exhibits greater stability and resistance to rancidity over time, as well as it can be used as biodiesel, too. Sunflower seed is a source of dietary fiber, some amino acids (especially tryptophan), vitamin E, several B vitamins (especially thiamine, pantothenic acid and folic acid). It is rich in cholesterol-lowering phytosterols, in protein (9-24%), as well as in minerals including magnesium and copper.

Botanical characteristics

Sunflower has a substantial but often shallow root system. Tap root can go up to 3 m depth with a large lateral spread of feeder roots the majority of which remains near the soil surface (up to 50 cm). The stem is robust, circular in section, ca. 3-6 cm in diameter with rough hairs and slight longitudinal ridges. It has a woody exterior filled with a stiff white pith. The stem height is 1-3 m. Varieties and hybrids of high seed-oil content are usually

shorter with smaller heads. Branching is unfavorable in crops grown for seed. Leaves are opposite on the lower stem (first three pairs) and alternate above. They are large, ovate and cordate carried on long petioles. The inflorescence is a disc-shaped capitulum (head) borne terminally on the main stem and branches. Its size is usually 10-30 cm in diameter. Flowers are of two types. The brightly colored, yellow, sterile ray (ligulate) flowers resembling petals are ordered in an outer row. Brown or purplish, fertile disc flowers are arranged spirally in the centre of the head. Their number is 600-1200 (*Figure 28*). The fruit (sunflower seed) is an achene of various colors: black, black with grey or white/light-grey stripe, dark grey with white/light-grey stripe, grey with white or grey stripe, white. Dark hull is usually related with high seed-oil content while light and striped hull with birdseed and confectionary purposes. Dark seeds are usually smaller, their 1000 grain content being 70-80 g. Confectionary seeds have a 1000 grain weight of 100-120 g.



Figure 28 Sunflower

According to the extended BBCH-scale, sunflower has the following principal phenological growth stages:

- 0: Germination
- 1: Leaf development
- 3: Stem elongation
- 5: Inflorescence emergence
- 6: Flowering
- 7: Development of fruit
- 8: Ripening
- 9: Senescence

Sunflower bud exhibits heliotropism: during the day, its faces move from east to west, while at night they return to an eastward orientation. In the flowering stage sunflower is not heliotropic anymore, heads are locked facing east. Flowers are protandrous and cross-fertilized, honey-bees being the almost exclusive pollinators. Flowers mature progressively from the periphery to the center of the disc: 2-4 rows at one time.

The centre of origin of sunflower is in North America (32-52° Northern Latitude: Arkansas, North and South Dakota, Kentucky, Missouri, Nebraska). *H. annuus* belongs to the family Asteraceae and it is diploid ($2n=34$). Nowadays primarily hybrid sunflowers are cultivated worldwide, however varieties can also be found especially among confectionary and ornamental genotypes.

Environmental requirements

Sunflower is grown in semi-arid regions of the world. Its effective heat unit is 1900-2500 (3000) °C. It tolerates both low and high temperatures. Sunflower germinates at 6-7 °C (confectionary varieties) or 7-8 °C (high oil varieties). Seedlings in the cotyledon stage can survive temperatures down to -5 °C. At later stages freezing temperatures may injure the crop. Temperatures below -2 °C can kill maturing sunflower plants.

Optimum temperatures for growth are 21 to 25 °C, but temperatures from 18 to 32 °C have little effect on productivity. Extremely high temperatures lower oil percentage, seed fill and germination.

Regarding transpiration coefficient (transpired g H₂O/g DM) of 577, sunflower is similar to wheat, soybean, fieldbean, oat, and rape, while it is 349 for corn and 34 for sorghum. It has, however a medium water requirement of 470-550 mm. It is drought tolerant owing to its extensively branched taproot, penetrating to 2 m. Maximum water requirement can be detected between the formation of disc primordia and the start of flowering (ca. 40%, 200 mm), as well as after flowering, between seed filling and oil accumulation (25-30%, 120-150 mm).

For initial development warm and rainy, for flowering warm and humid (22-24 °C), for seed filling and ripening dry, moderately warm (18-20 °C) and sunny weather is beneficial. In the last period 10 rainy days per month are optimal. Humid, rainy weather stimulates the occurrence of disc diseases.

Sunflower grows in a wide range of soils from sands to clays. Best are medium compact loamy soils of good temperature and water management and good general condition. Its pH optimum is 6.5-7.5. Primarily cernozems but also brown forest soils, meadow and alluvial soils, humic sand and improved alkaline soils are preferred. Sunflower tolerates soils of inferior quality (eroded, shallow tilled, low humus sand, alkaline, etc.) but depression in yield quantity and quality can be expected.

Cultivation

The best forecrops of sunflower are winter and spring cereals, as well as sweet corn. Forecrops of medium quality are silage maize, corn, sorghums, temporary grasses. Pulses and legumes are inferior forecrops due to enriching soil in nitrogen that increases disease-susceptibility and is not utilized efficiently. Tobacco, hemp, flax, tomato and other crops susceptible for grey and white mold, as well as sugarbeet, potato, chicory and sunchoke leaving contagious residues must be avoided two years prior to sunflower. Rotation is 5 years, in the case of broomrape infection 6-7 years. It can be followed by maize, spring barley, oat, sorghum, annual forages and winter wheat. However, sunflower is not suitable as forecrop for sugarbeet and potato due to its high water consumption and causing weediness, as well as for pulses and legumes due to inhibiting the formation of root nodules for a while.

Table 44 Nutrient requirement of sunflower

Nutrient uptake to 1 ton of grain				
N: 40 kg/t	P ₂ O ₅ : 30 kg/t	K ₂ O: 70 kg/t	CaO: 24 kg/t	MgO: 12 kg/t

Tillage resembles that applied for maize. Basic fertilization and sowing data can be found in *Tables 44* and *45*, respectively. In general, the effective ingredient doses are 30-80 kg/ha N, 40-120 kg/ha P and 80-140 kg/ha K. Sunflower has special Ca and Mg requirement.

Inter-row cultivation is used to improve soil structure and as an alternative or supplement to chemical weed control by herbicides.

Irrigation is not applied to avoid head diseases.

Table 45 Sowing data of sunflower

Sowing date: - oil-type - confectionary-type	10-25. April (8-12 °C soil temperature) 1-15. April (7-9 °C soil temperature)
Row distance:	70-76.2 cm
Sowing depth:	4-7 cm
Seed rate: - oil-type - confectionary-type	42-55,000 (65,000) seeds/ha 34-43,000 seeds/ha 3-4 kg/ha
1000 seed weight: - high oil - confectionary-type	60-70 g 100-200 g

Diseases

Viral diseases

Sunflower mosaic virus (SMV), BWYV, TBBV

Phytoplasma diseases

Aster yellows phytoplasma

Bacterial diseases

Erwinia stalk rot and head rot (*Erwinia carotovora*), bacterial wilt (*Pseudomonas solanacearum*), apical chlorosis and bacterial leaf spot (*Pseudomonas syringae*)

Fungal diseases

Phomopsis brown stem canker (*Phomopsis/Diaporthe helianthi*), Sclerotinia basal stalk rot and wilt, mid-stalk rot, head rot (*Sclerotinia sclerotiorum*), Botrytis head rot/gray mold (*Botrytis cinerea*), downy mildew (*Plasmopara halstedii*), charcoal rot (*Macrophomina phaseolina*)

Pests

Banded sunflower moth (*Cochylis hospes*), cutworms, headclipper weevil (*Haploryhynchites aeneus*), longhorned beetle (*Dectes texanus*), midge (*Contarinia schulzi*), palestriped flea beetle (*Systema blanda*), red and gray seed weevils (*Smicronyx fulvus*), sunflower beetle (*Zygogramma exclamationis*), sunflower bud moth (*Suleima helianthana*), sunflower moth (*Homoeosoma electellum*), sunflower seed maggot (*Neotephritis finalis*), sunflower stem weevil (*Cylindrocopturus adpersus*), thistle caterpillar (*Vanessa cardui*), wireworms, nematodes

Harvesting

Sunflowers are biologically mature at a seed moisture of 30-35% and head moisture of 70-80%. Harvesting can be performed at a seed moisture content of 15-18% when head moisture content is 30-35%. To ensure uniform maturity, desiccants or growth regulators are usually applied at a seed moisture content of 30-35% which is followed by harvest in 5-7 or 14-18 days, respectively. Sunflower is direct combined, preferably with a combine equipped with a header cutterbar lifted to 50-80 cm. Seed loss is 4-6%, under unfavorable conditions 15-25%. Seeds should be below 10(8)% moisture for long term storage.

2.4.2. Rapeseed (canola) (*Brassica napus* L. *oleifera*)

Rapeseed is the third most important oilseed crop in the world, according to its growing area (34,085,066.00 ha). The global production is 65,058,240.00 tons (FAO, 2012). Rapeseed oil (00 genotypes) is used by food industry (cooking oil, margarine, etc.), cosmetic industry (creams, etc.), textile industry, soap, paint, plastic and leather production or processing, production of coolants and slushes in heavy industry. It is a valuable raw material of biodiesel production (regulation: oleic acid: 51-80%, linolenic acid: 2-10%). In developing countries it is still used for lighting. By-products of oil-extraction (00 genotypes) are food for livestock (especially for ruminants). The whole plant can be utilized as green forage and for grazing. Rapeseed can be used as green manure, furthermore it is an excellent forecrop (early harvest, little stem and root residues, etc.).

Table 46 Fatty acid composition of canola oil

Compound	Family	% of total
Oleic acid	ω -9	61%
Linoleic acid	ω -6	21%
Alpha-linolenic acid	ω -3	9-11%
Saturated fatty acids		7%
Palmitic acid		4%
Stearic acid		2%
Trans fat		0.4%

Rapeseed has a crude oil content of 46-48% (traditional genotypes) or 42-44% (00 genotypes). Traditional rapeseed genotypes has a high (>45%) erucic acid and glucosinolate (>150 $\mu\text{mol/g}$) content. Erucic acid (22:1) is considered to cause severe health problems such as liver degeneration, nephritis, myocarditis and decreased growth. Glucosinolates are sharp-tasting and maybe poisonous (goiter inducing effect) compounds inhibiting the utilization of rapeseed meal for feeding. Canola or Double Zero (00) Rapeseed has 0-2% erucic acid and <150 $\mu\text{mol/g}$ glucosinolate content making it suitable especially for human consumption, animal feeding and biodiesel purposes. The fatty acid composition of canola oil is shown in *Table 46*.

Botanical characteristics

Rapeseed has a tap root system of ca. 2 m in depth, with secondary roots growing outward and downward from the tap root. After emergence, the plant quickly establishes a rosette with older, bigger leaves at the base, younger leaves developing in the centre. Canola plants can produce 9 to 30 leaves on the main stem depending on variety and growing conditions. *B. napus* plants grow 75-175 cm tall and have a distinct main stem with from four to six secondary branches (*Figure 29*). Canola flowers are bisexual and develop in terminal racemes. The diagonally opposite, yellow petals form a cross. Seeds develop in a 2-celled, elongated capsule (silique or pod). Between 15 and 25 seeds are produced per pod. Its 1000 grain weight is 3.5-6 g.

The centre of origin of rapeseed is the Mediterranean basin (Southwest Europe, North Africa). The rapeseed belongs to the family Cruciferae. *B. napus* is an amphidiploid

(AACC, $2n=38$) of *B. oleracea* (CC, $2n=18$) and *B. rapa* (AA, $2n=20$). Canola was bred in Canada in the early 1970s.



Figure 29 Oilseed rape

According to the extended BBCH-scale, rapeseed has the following principal phenological growth stages:

- 0: Germination
- 1: Leaf development
- 2: Formation of side shoots
- 3: Stem elongation
- 5: Inflorescence emergence
- 6: Flowering
- 7: Development of fruit
- 8: Ripening
- 9: Senescence

Canola flowers are entomophilous. Fertilization usually results from self-pollination. Outcrossing occurs at levels of ca. 30%.

Environmental requirements

Canola is adapted primarily to the cool extremes of the temperate zones. Optimum are the moderate warm and humid conditions. Minimum temperatures for growth is 8 °C. Effective heat unit until blooming is 170-210 °C. Rapeseed withstands frost to -18-22 °C on dry soil and to -6-8 °C on wet soil. Winter varieties are grown where snow covers or mild winters are common. Planting date has a dramatic effect on survival. Too early sowing results in excess growth leading to freezing out or suffocation. Too late sowing, however, can result small plants with thin root system which are threatened by the negative effects of freeze-thaw cycles of soils. Optimal overwintering can be expected at a developmental stage of a rosette with 8-10 leaves.

Canola requires 400-500 mm precipitation with maximums at emergence, intensive growing and before flowering. At flowering humidity of 80% is preferred.

Canola does best on medium textured, well drained, medium compact or loose soils. It is tolerant of a soil pH as low as 5.5 and saline conditions, optimum being 6.5. Best are

different types of brown forest soils and cernozems. It can be, however, grown in sand, meliorated alkaline and alluvial soils, slopy fields and soils of shallow tilth, too.

Cultivation

Rapeseed does not have special forecrop requirements; however crops harvested early, 4-6 weeks (15-20. July) prior to rapeseed sowing are preferred. Good forecrops are winter barley, early winter wheat, pea, winter and spring forage mixes, crimson clover, etc. Medium maturity winter wheat, spring barley, early potato and alfalfa broken up early can still be applied. Oat, legumes broken up late, and forecrops harvested after the end of July should be avoided. Rotation is 5 years. Rapeseed is one of the best forecrops of wheat.

Following stubble clearing, primary tillage can be performed by ploughing (on wet soil, 20-25 cm depth) or disc harrowing (on dry soil, 10-13 cm depth). Primary tillage must be finished ca. 4 weeks prior to sowing. Seeding into a smooth, firm seedbed assures a uniform seeding depth and even emergence. Seedbed should be 1.5-3 cm deep and compact. Canola can be successfully established also with reduced and conservation tillage and direct seeding.

Table 47 Nutrient requirement of rapeseed

Nutrient uptake to 1 ton of grain				
N: 55 kg/t	P ₂ O ₅ : 35 kg/t	K ₂ O: 43 kg/t	CaO: 30 kg/t	MgO: 10 kg/t

Table 48 Sowing data of rapeseed

Sowing date:	25. August-15. September
Row distance:	24 cm
Sowing depth:	1.5-3 cm
Seed rate: - variety (rare) - hybrid	1.0-1.4 million seeds/ha after winter: 80-100 plants/m ² 600-800,000 seeds/ha after winter: 50-60 plants/m ² 2.5-6 kg/ha
1000 seed weight:	3.5-6 g

Basic fertilization and sowing data can be found in *Tables 47* and *48*, respectively. In general, the effective ingredient doses are 50-110 kg/ha N, 70-80 kg/ha P and 80-100 kg/ha K. Canola has a special calcium, magnesium and boron requirement.

Growth regulators are frequently applied in the autumn to prevent stem elongation before winter.

Irrigation can be applied early autumn and early spring.

Diseases

Downy mildew (*Peronospora brassicae*), white mold (*Sclerotinia sclerotiorum*), Alternaria black spot (*Alternaria brassicae*), white rust (*Albugo candida*), grey mold (*Botrytis cinerea*), clubroot (*Plasmodiophora brassicae*), black leg (*Phoma lingam*), light leaf spot (*Cylindrosporium* spp.)

Pests

Flea beetles (*Phyllotreta* sp.), Bertha armyworms (*Mamestra configurata*), bronzed field beetle (*Adelium brevicorne*) larvae, diamondback moths (*Plutella xylostella*), large white butterfly (*Pieris brassicae*), Harlequin bug (*Murgantia histrionica*), Lygus bugs (*Lygus* spp.), pollen beetle (*Meligethes aeneus*), root maggots (*Delia* spp.), nematodes

Harvesting

Rapeseed is flowering long which results in an elongated ripening. It reaches primary technical maturity at a seed moisture of 30-40%, pods are golden-yellow, seeds can be severed by finger pressure. To ensure uniform maturity, desiccants or growth regulators are usually applied at a seed moisture content of 25-30% which is followed by harvest in 5-7 or 14-18 days, respectively. Secondary technical maturity is reached at a seed moisture of 16-19%, pods are brown, seeds are black. Canola is harvested by direct combining. Seeds should be below 11(9-10)% moisture for long term storage.

2.4.3. Poppy (*Papaver somniferum* L.)

Poppy (a.k.a. opium poppy) is utilized in several ways: food (alkaloid content <0.1%), industrial products (alkaloid-based medicines - alkaloid content >0.1% up to 10%; oil – 40-56%; cosmetics, etc.), bird's food, ornamental plant (flower or dry pod), etc. Poppy seeds are used as ingredient in foods, as traditional medicine, and they are pressed to yield poppyseed oil. Poppy straw (poppy capsule/poppy chaff/poppy head/poppy pod) is opium poppy harvested fully mature and dry, separated from the ripe seeds. Since the world patent of János Kabay (1927) for the chemical process of extracting morphine from it, poppy straw became the major source of many opiates and other alkaloids, such as morphine (0.15-1.8% dry pod weight, d.p.w.), codeine (0.05-0.6% d.p.w.), thebaine, papaverine, narcotine/nascopine and narcotoline. Poppy straw is occasionally a source of illegal morphine processed into illegal heroin, while raw opium is gained from latex leaking from shallow cuts in the immature seed pods.

Botanical characteristics

Poppy has a tap root system of ca. 1 m in depth, with a low number of side roots which get thick near the soil surface thus giving support to the plant. The stem can be 50-150 cm tall. The stem and the leaves are strongly glaucous, giving a greyish-green appearance, and sparsely covered with coarse hairs. The leaves are lobed and clasp the stem at the base. The flowers are up to 120 mm in diameter. They have normally four white, mauve or red petals, sometimes with dark markings at the base. The fruit is a rounded capsule with 12-18 radiating stigmatic rays on the top (*Figure 30*). The kidney-shaped seeds are of various color, e.g. blue, brown, black or white. Its 1000 grain weight is 0.25-0.6 g. The seeds contain very low levels of opiates, compared to the seed pod and straw. All parts of the plant exude white latex when wounded.

The centre of origin of poppy is the southern and eastern part of the Mediterranean basin, the region of the Aegean Sea. Poppy belongs to the family Papaveraceae and it is diploid ($2n=22$).

Poppy has several subspecies or varieties/cultivars. They are different in the color of the flower, in number and shape of petals, in number of flowers and fruits, in number of seeds, in color of seeds, in production of opium, etc.

Poppy has the following principal phenological growth stages:

- 1: Seed and dormant germ
- 2: Germination
- 3: Leaf rosette
- 4: Stem elongation (internode elongation and branching)
- 5: Flowering, seed development, pod growing
- 6: Seed and pod ripening

Poppy can be both self- and cross-pollinated.



Figure 30 Opium poppy

Environmental requirements

Poppy has a growing period of 120-160 days or 250-270 days if sown in spring or autumn, respectively. The effective heat unit requirement is 2000-2200 °C. It germinates at 3-5 °C. Below -3 °C it will be damaged. At stem elongation it needs 16-18 °C and it has the highest nutrient and water requirement at this stage. At flowering and ripening 21-23 °C is preferred. During the whole growing period a gradual increase in temperature is optimal. Poppy needs 280-300 mm water with maximums at growth stages of leaf rosette – stem elongation as well as budding – early flowering. Excess of water after flowering can result in the cease of growth and development. Poppy needs much light, >20,000 lux for flower development. The length and strength of insolation increases alkaloid content in poppy straw. Poppy is sensitive for strong wind that can remove loose soil from growing seedlings as well as for sand-blast.

Poppy does best on early warming, medium textured or looser humic sand, cernozem or brown forest soils. It prefers pH 7-8 to pH 6. Loose sand, hard meadow and acidic (pH <6) soils should be avoided.

Cultivation

Small grain cereals and potato are the best forecrops of poppy. It can be efficiently grown after rapeseed, mustard and sugar beet if weediness is considered. Maize, sunflower and perennial legumes should be avoided as forecrops. Rotation is 4-6 years. Poppy is one of the best forecrops of winter cereals.

The tillage system resembles those applied for winter or spring cereals. The main aspect is the preparation of a shallow (1-1.5 cm) and compact seedbed.

Basic fertilization and sowing data can be found in *Tables 49* and *50*, respectively. In general, the effective ingredient doses are 100-150 kg/ha N, 50-80 (90-110) kg/ha P and 60-90 (80-100) kg/ha K. Opium poppy has a special boron requirement.

Table 49 Nutrient requirement of poppy

Nutrient uptake to 1 ton of grain				
N: 45 kg/t	P ₂ O ₅ : 15 kg/t	K ₂ O: 50 kg/t	CaO: 20 kg/t	MgO: 3 kg/t

Table 50 Sowing data of poppy

Sowing date: - spring - winter	25. February-15. March September
Row distance:	45 cm (12-24 cm)
Sowing depth:	1.0-1.5 cm
Seed rate: - sown - yielding plant	1.2 million seeds/ha (1.5 million seeds/ha) 500.000-700.000 plants/ha 0.5-0.7 kg/ha
1000 seed weight:	0.25-0.6 g

Pelleted seeds are primarily used for alkaloid poppy, and is recommended especially for wet conditions. To avoid or reduce the need for thinning, poppy seeds can be mixed with irradiated poppy or mustard seeds in 1:4. Plantlets developing from irradiated seeds die at seedling stage. Other possibility is to mix poppy seed with carrot seed (1:4), or in kitchen gardens with wheat semolina, with maize grits, with ground and silted coal slug, etc.

Diseases

Downy mildew (*Peronospora arborescens*, *P. papaveracea*), poppy fire (*Pleospora papaveraceae*/*Helminthosporium papaveris*), bacterial stem rot (*Erwinia carotovora*), Fusarium dry rot (*Fusarium oxysporum*), *Dendryphion* spp., (*Macrosporium bresadolae*), powdery mildew (*Erysiphe communis*), grey mold (*Botrytis cinerea*)

Pests

Capsule weevil (*Ceutorhynchus maculaalba*), poppy capsule midge (*Dasyneura papaveris*), black bean aphid (*Aphis/Doralis fabae*), poppy gall wasp (*Timaspis papaveris*), poppy root weevil (*Stenocarus fuliginosus*), *Chlinodiplasis papaveris*, cabbage moth (*Mamestra brassicae*)

Harvesting

Ripe poppy pods are dry, yellowish in color, the seeds have the color typical for the genotype. Pod moisture content is 10-12(16)%, seed moisture content is 9-12%. Pods are cut by hand or by a cutter/harvester with a stem part of 10-15 cm. Harvesting is performed in one or two turns.

The yield of pod and seed is 0.6-1 t/ha and 0.8-1.2 t/ha, respectively. In winter poppy 1-1.2 t/ha as well as 1-1.5 t/ha, respectively.

Seed:pod:straw residue percentage is 1:1.5:0.8-0.9. Poppy seed can be stored at a moisture content of 9%.

2.4.4. Flax grown for seed oil

Basic data of the cultivation of flax grown for seed oil can be found in *Table 51*.

2.4.5. Test your knowledge

List and describe the groups of oilseed crops assorted by the drying of their oil

Describe the importance and quality of sunflower/rapeseed/poppy

Describe the botanical characteristics of sunflower/rapeseed/poppy

Describe the environmental requirements of sunflower/rapeseed/poppy

Describe the main aspects of cultivation of sunflower/rapeseed/poppy

Give the sowing data of sunflower/rapeseed/poppy

List the diseases and pests of sunflower/rapeseed/poppy

Describe the harvesting and storage of sunflower/rapeseed/poppy

Table 51 Basic data of flax growing

Flax (<i>Linum usitatissimum</i> L.) 2n=30		
	for seed (linseed)	for fiber
Features		
	<ul style="list-style-type: none"> - grains used for human consumption - its drying oil (35-37%) is used by chemical, cosmetic, textile, printing and pharmaceutical industry - linseed cake of high protein content (35-50%) used for animal feeding - stem residues of high fibre content used for paper production - prefers higher average temperature than flax - precipitation at flowering results in higher number of pods - precipitation over average in other growth stages is unfavorable - rotation of 4-6 years 	<ul style="list-style-type: none"> - contains fine and white bast fibers (occurring in the phloem parenchyma) composed mainly of cellulose - used for the production of linen textiles (soft, lustrous and very water-absorbent) - compared to linseed: weaker root system, long stem without branches (branches on the top only), narrower, less nodding leaves, fewer pods, smaller seeds - requires cooler, more humid climate - rotation of 4-6 years - sowing in 4-6 cm stripes is preferred for a dense population - extremely sensitive for weeds
Nutrient supply (kg/ha)		
N:	90-110	45-54
P ₂ O ₅ :	60-100	68-80
K ₂ O:	70-100	135-162
Data of sowing		
Date:	15-31. March (15. April)	15-31. March
Row distance:	(12) 24 cm	12 cm
Sowing depth:	2-3 cm	2-3 cm
Seed rate:	13 (15-18) million/ha 90-140 kg/ha	25-29 million/ha 140-160 kg/ha
1000 seed weight:	6-9 g	3-6 g
Harvesting		
	<ul style="list-style-type: none"> - desiccation at late yellow ripening is usually needed - full ripening at seed moisture <15%, bolls are brown - harvesting with combine - storage at max. 9% seed moisture Yield: 1-1.3 t/ha 	<ul style="list-style-type: none"> - harvesting at early yellow ripening - traditionally harvested by lifting (with roots) - lifted plants are tied in bundles (stooks), or collected after swathing

2.5. INDUSTRIAL CROPS

2.5.1. Hemp (*Cannabis sativa* L.)

Hemp is one of the oldest cultivated plants. The various parts or organs of the plant can be utilized for a wide range of purposes. Bast fibers are used in textile industry (sacks, cordage, canvas, clothes, etc.), paper industry, building industry (fibreboards, insulation blocks, concrete blocks with hemp, etc.) and composite, hemp plastic materials for car interiors, sink basins, etc. Hemp hurds (shives) are used in building industry (fibreboards, insulation, stuccos/plasters, etc.), as well as for animal bedding, mulch, compost for mushroom cultures, etc. Leaves are used for animal bedding and compost, the cellular liquid of green plants as solvent. The whole plant can be used for the production of alcohol fuel or as biomass for energy production. Hemp seed has a high (30-33%) content of drying oil. This can be used for the purposes described at oilseed crops, including biodiesel, while the seed cake as animal food, protein powder, gluten-free flour or beer-additive. Hemp has several agrotechnical advantages, too. Because of its height, dense foliage and its high planting density as a crop, it effectively kills tough weeds. Furthermore, it has few pests, its deep root system loosens the soil and leaves it in good condition.

Botanical characteristics

Hemp is an annual plant with a deep taproot system and is capable of very rapid growth (4-6 cm/day). Fibre hemp plants grow to 2-4 m tall without branching (*Figure 31*). The stem has an outer bark that contains the long, tough bast fibers. Bast (skin) fibres are collected from the phloem (bast). They support the conductive cells of the phloem and provide strength to the stem. They are similar in length to soft wood fibers and are very low in lignin content. Hemp rope, textiles and clothing is made from these fibers. The core contains the hurds or shives (short fibers) similar to hard wood fibers and these are used for building, particleboard (MDF), pet bedding, etc. Valuable fibres of the phloem must be separated from the xylem material (woody core). This process is called retting. Plants grown for grain production may branch and reach heights of 2-3 m.



Figure 31 Hemp

The growth stages of hemp are the following:

1. Germination, emergence
2. Seedling growth, leaf development
3. Big period of growing (from the 5. pair of leaves to appearance of flower buds)
4. Inflorescence initiation
5. Flowering
6. Development of fruit

Hemp is dioecious, however monoecious genotypes were are bred. Besides varieties, hybrids are also cultivated. Besides dioecious hybrids, unisexual hybrids are also in use. This case the pure female F₁ originating from a monoecious x dioecious crossing is used for seed production while F₂ is the fibre producing generation.

Male hemp is different from the female individuals in several characteristics: it grows faster, its growing period is 5-6 weeks shorter, its stem is taller and thinner, it has higher fibre content and better fibre quality due to the higher percentage of primary fibres.

The centre of origin of hemp is Centre Asia. From here it spread to north (Northern hemp and Central Russian hemp) as well as to south (Meditarranean hemp). Hemp belongs to the family Cannabinaceae and it is diploid (2n=20).

Cannabis sativa L. var. *vulgaris* (common hemp) has a THC (Tetrahydrocannabinol) content of <0.2%. *C. sativa* var. *indica* (Indian hemp) has a high THC content of >0.2% (up to 20%). *C. sativa* var. *ruderalis* is wild hemp with a low THC content.

Environmental requirements

Hemp has a growing period of 110-115 day and a heat unit requirement of 1800-2000 °C (fibre) or 2500-3000 °C (seed). Minimum temperature for germination is 1-2 °C (optimum: 5-10 °C). It withstands frost to -5 °C. Till the closing of leaf canopy 10-15 °C, while in the big period of growth (summer months) 20-25 °C are optimal. Sunlight may affect fibre quality. The dense population of fibre hemp requires much water (500-700 mm) but it utilizes water efficiently. Maximum water requirement is during the intensive growth.

Hemp requires well drained, loam soil with high humus content, deep tith and pH above 6.0 (optimum: pH 7.0-7.5). Higher clay content of the soil results in lower yield of grain or fibre. Hemp is very sensitive to soil compaction. Young plants are very sensitive to wet soils or flooding during the first 3 weeks or until growth reaches the fourth internode (ca. 30 cm tall).

Poorly structured, drought-prone sandy soils as well as those with a shallow tith should be avoided.

Table 52 Nutrient requirement of hemp

Nutrient uptake to 1 ton of yield				
N: 10 kg/t	P ₂ O ₅ : 4 kg/t	K ₂ O: 20 kg/t	CaO: 16 kg/t	MgO: 6 kg/t

Cultivation

Best forecrops of hemp are small grain cereals and other crops harvested early and leaving much moisture in soil. Sunflower, flax and other water-demanding crops should be avoided. A rotation of 4 years is advised.

Hemp requires a deep tillage. Basic fertilization and sowing data can be found in *Tables 52* and *53*, respectively. In general, the effective ingredient doses are those applied for wheat: 12-150 kg/ha N, 70-100 kg/ha P and 100-120 kg/ha K. Chloride inhibits fibre formation thus K₂SO₄ should be used instead of KCl.

Table 53 Sowing data of hemp

Sowing date:	20. March-10. April
Row distance:	12 cm
Sowing depth:	3-4 cm
Seed rate: - early - late	3.0-3.5 million seeds/ha 2.0-2.5 million seeds/ha 40-70 kg/ha
Established population:	200 plants/m ²
1000 seed weight:	17-23 g

Diseases

Damping-off (*Pythium debaryanum*), hemp canker (*Sclerotinia sclerotiorum*), grey mold (*Botrytis cinerea*), hemp rust (*Melampsora cannabina*), brown leaf spot and stem canker (*Ascochyta* spp.), nematodes

Pests

Flea beetle (*Psylloides attenuata*), hemp stem-borer (*Grapholita delineana*), European corn borer (*Ostrinia nubilalis*)

Harvesting

Highest stalk yields are given by dioecious varieties originating in southern Europe. Male hemp reaches technical maturity 20-25 days before the female. Technical maturity is when male plants are in 50% flowering while pollen is shed and inflorescences just appeared on female plants. Defoliation can be applied in the case of big amount of leaves. It is followed by harvest in 8-10 days.

Traditionally, hemp is harvested by hand, by a special cutter-binder and a stabile baler, or fully mechanized by a hemp-harvester. After cutting (2-3 cm above ground), hemp stalks are lying in windrows for several days. Stalks are gathered and tied into bundles (diameter: 20-25 cm) by a machine. Bundles are shocked (40 bundle/shock), finally compressed and baled (80 bundles/bale, 16% moisture).

2.5.2. Tobacco (*Nicotiana tabacum* L.)

Besides the usage of dried tobacco leaves in tobacco industry (cigarettes, cigars, pipe tobacco, flavored shisha tobacco, as well as snuff, chewing tobacco and dipping tobacco), tobacco alkaloids are utilized in chemical industry for the production e.g. pesticides.

The most important alkaloid of tobacco, nicotine causes death already in an amount of 0.04-0.06 g. Tobacco genotypes of good quality contains 0.5-1.5% in leaf dry matter. Cultivars of crude leaf structure contain 1.6-3.0% while *N. rustica* >5% nicotine. Nicotine is a substitute of nicotine with milder effect, while anabasine is more poisonous than nicotine and is used as insecticide. Carbohydrates (except for starch) have a crucial positive role in the determination of quality and aroma. They give 40-50% of dry matter. Organic acids (e.g. citric acid giving 0.6-9.2% of total organic acids) bind a part of nicotine thus improving the flavor of smoke. Potassium improves drought resistance of the plants carbohydrate synthesis in leaves and contributes to better burning. Calcium in high proportion has negative effect due to binding organic acids. High phosphorous and

chloride levels provide both negative burning and taste characteristics. High protein and nitrate content decrease burning characteristics and smoke quality. In tobacco of good quality nitrogen level is <8%.

Tobacco has various types according to their botany and utilization:

- Brightleaf tobacco ("Virginia tobacco") - most widely used worldwide, especially suitable for artificial drying
- Burley tobacco - even ripening of leaves thus the whole plant is harvested
- Cavendish - more a process of curing and a method of cutting tobacco than a type; it is used to bring out the natural sweet taste in the tobacco
- Criollo tobacco - primarily used in the making of cigars
- Turkish tobacco - a sun-cured, highly aromatic, small-leafed variety
- Perique tobacco - used as a component in many blended pipe tobaccos
- Wild tobacco (*Nicotiana rustica*) – extreme high nicotine content (>5%).
- others: Aromatic fire-cured tobacco, Dokha tobacco, Shade tobacco, White burley, Y1 strain

Botanical characteristics

Tobacco has a strong tap root system but during the collection of seedlings the original roots are damaged and a shallow system of adventitious roots develops after transplanting. Plant height ranges from 90 to 240 cm. Tobacco plants can produce between 10 and 40 leaves. They vary in size from 15 to 100 cm, in shape from long, narrow to broadly ovate, in angle from upright to horizontal, and in color (*Figure 32*). Due to their differences in quality, the leaves are divided into groups based on the harvesting insertion (from bottom to top): primings (P, 6%), lugs (X, 14%), middle leaves or cutters (C, 28%), upper leaves (B, 42%) and tips (10%).

Tobacco has a terminal raceme panicle. The color of flowers vary from pink and purplish to white. Flowering order is from top to bottom. The fruits are capsules. Seeds are dark or light brown, their 1000 grain weight is the smallest among crops: 0.09 g.



Figure 32 Tobacco

The centre of origin of tobacco is Central and South America. It belongs to the family Solanaceae. *N. tabacum* is an amphiploid species ($2n=48$) likely resulting from an interspecific cross between *N. sylvestris* ($2n=24$) and *N. tomentosiformis* ($2n=24$).

The principal growth stages of tobacco based on the BBCH scale:

0. Germination

1. Leaf development (0. seedling; 1. field plant)
2. Formation of side shoots (0. ground suckers; 1. upper stalk/head suckers)
3. Stem elongation and crop cover (0. stem elongation – seedlings;
1. stem elongation – field plant; 2. crop cover within rows; 3. crop cover between rows)
4. Development of harvestable vegetative plant parts (i.e. ripening of leaves)
5. Inflorescence emergence
6. Flowering (main stem)
7. Development of fruits (i.e. seed capsules)
8. Ripening of seeds
9. Termination of crop (harvesting and curing: 0. leaf harvesting phase; 1. colouring phase;
2. lamina drying phase; 3. mid-vein drying phase)

Environmental requirements

Tobacco, due to its origin requires warm conditions throughout its growing period. Effective heat unit is 3000-3500 °C (in temperate climate 2600-2700 °C of this on the field). It germinates at 13-15 °C (optimum: 25 °C). Daily average temperature should be 20-22 °C while daily temperature difference must be <10 °C. It is sensitive for frost, -3-4 °C deteriorates yield. At the beginning of development temperature, in the final part of development sunshine has decisive role. Cool weather results in big leaves and poor quality while warm and dry weather generates smaller leaves of good quality in the second half of the growing period. Water supply has an important role in the determination of leaf quality through turgor pressure. Furthermore, in dry years nicotine level becomes higher. Virginia and Burley tobaccos require 350-450 mm water, Burley exhibiting slightly higher needs. Air humidity in excess during leaf development can contribute to the occurrence of diseases. Wind, shower and hail can cause severe damages on leaves. During maturation sunshine and warm, at harvest dry and warm weather is preferred.

Tobacco prefers well aerated, loose soils of deep tilth. Virginia tobacco has a pH optimum of 5.5-7.2, pH optimum of Burley is 7-8. On compact soils leaves will have coarse while on loose soils fine-textured leaves. High nitrogen content is unfavorable.

Cultivation

Tobacco does not have special requirements for forecrops. It can be cultivated in monoculture for 2 years. Best forecrops are wheat, barley and rye. Forage mixes, lupines and sweet clover are of mediocre quality. Perennial legumes, pulses, sorghum, maize, sunflower, sugar beet and melone are bad forecrops. Among others, potato, pepper, tomato, eggplant, hemp, flax and cucumber should be avoided. Tobacco itself is good forecrop for small grain cereals and other non-relative plants.

Basic tillage steps are the same as described for other spring crops. Deep tillage is not necessary. Ridge planting is also common. It prevents root rot and discoloration of lower leaves, and improves harvestability of them. It should be 30-35 cm high at a row distance of 110 cm.

Basic fertilization data can be found in *Table 54*. In general, the effective ingredient doses are those applied for wheat: 30-50 kg/ha N, 60-80 kg/ha P and 180-200 kg/ha K. Chloride decreases quality and burning characteristics, thus K₂SO₄ should be used instead of KCl.

Tobacco is sown in the middle of February, into a special medium composed of turf (50%), farmyard manure (25%) and river sand (25%) in cold frames, hot bed or plastic tunnel greenhouse. Seed rate is 0.1 g/m² (= 900-1000 seeds/m²) with seeds of a 1000 grain weight of 0.09 g. Soil must be wet in a depth of 20-25 cm. For germination 13-15 °C, for further

development temperature raised from 15 to 32 °C is needed. Irrigation is necessary with a dose of 2.5-3.5 l/m²/day. Hardening of seedlings must be started 8-10 days prior to transplanting by aeration and lower level of irrigation intensity. In the last two days intensive irrigation is needed to decrease root damage. Seedlings of 5-7 leaves are transplanted after 4-5 weeks of growing. For manual transplanting seedlings of 10-15 cm, for mechanical transplanting seedlings of 15-18 cm are preferred. Ca. 50-70 m² of nursery area is needed for the transplanting of 1 ha.

Seedlings can also be grown in trays filled with compost and floating on water. It is a more sophisticated technique resulting in better quality seedlings with a strong root system. However, it is more expensive requiring much investment. The crucial step of this method is the trimming of seedlings four times to give a homogeneous population, to strengthen plantlets and delay transplanting.

Basic data of transplanting can be found in *Table 55*. Seedlings wasted away must be supplemented in 7 days. In dry conditions, tobacco must be irrigated from the height of 50 cm to flowering. Inter-row cultivation (4 times) is used to improve soil structure and as an alternative or supplement to chemical weed control by herbicides.

Tobacco crop needs to be topped prior to the development of flowers to improve quality and yield. Only 1-2 leaves are removed in well developed population, 2-3 in the case of late transplanting and 4-5 in supplementary populations. Lateral shoots developing after topping must be removed manually or chemically. In the case of mature plants and rainy weather they need not be removed.

Table 54 Nutrient requirement of tobacco

Nutrient uptake to 1 ton of tobacco		
N: 45 kg/t	P ₂ O ₅ : 15 kg/t	K ₂ O: 80 kg/t

Table 55 Transplanting data of tobacco

Planting date:	20-30. April (15-20%) 1-15. May (55-60%) 16-31. May (20-30%)
Row distance:	90-110 cm
Plant-to-plant distance:	35-50 cm
Transplanted seedlings:	(25) 28-29 ezer/ha

Diseases

Tobacco mosaic virus (TMV), cucumber mosaic virus (CMV), potato Y virus (PVY), wildfire (*Pseudomonas syringae* pv. *tabaci*), blue mold/downy mildew (*Peronospora tabacina*), brown spot (*Alternaria* spp.), Fusarium wilt (*Fusarium oxysporum*), grey mold (*Botrytis cinerea*), stem rot of transplants (*Pythium* spp.), nematodes

Pests

Tobacco flea beetle (*Epitrix hirtipennis*), vegetable weevil (*Listroderes costirostris obliquus*), tobacco budworm (*Heliothis virescens*), tobacco hornworm (*Manduca sexta*), green peach aphid (*Myzus persicae*), whitefringed beetle (larvae) (*Graphognathus* spp.), stink bugs, wireworms

Harvesting and curing

Tobacco reaches technical maturity when the leaf surface is bright, yellowish green, the mid-vein of leaves gets lighter and it breaks snapping. Tobacco is harvested in ca. 5 rounds by pulling individual leaves off the stalk as they ripened. The leaves ripen from the ground upwards, so a field of tobacco harvested in this manner will involve the serial harvest of a number of "primings," beginning with the volado leaves near the ground, working to the seco leaves in the middle of the plant, and finishing with the potent ligero leaves at the top. Leaf yield is 1.5 tons/ha. Burley tobacco ripens homogeneously thus the entire plant is harvested at once by cutting off the stalk at the ground with a tobacco knife. It is then speared onto sticks, four to six plants a stick and hung in a curing barn.

After being harvested, tobacco needs to be cured to prepare the leaf for consumption. Curing methods vary with the type of tobacco grown, and tobacco barn design varies accordingly.

Air-cured tobacco is hung in well-ventilated barns and allowed to dry at 28-30 °C, 76-80% humidity over a period of four to eight weeks. Cigar and burley tobaccos are air cured.

Flue curing is followed in the production of high grade cigarette type tobacco. Tobacco is cured under artificial heat in flue curing barns. Leaf moisture content is reduced from 80% to 20-25(16-18)%. The steps are:

1. Yellowing of leaves - 32-36 °C, 36-48 hours, 86-90% humidity
 2. Fixing of colour - 40-45 °C, 16-24 hours, 40-45% humidity
 3. Drying of lamina - 57-65 °C, 24-36 hours, 30% humidity
 4. Drying of mid-vein - 70-75 °C, 24-36 hours, 20% humidity
 5. Cooling, softening - 20 °C, 16-20 hours, 20-35% humidity
- Other curing methods are fire and sun curing.

2.5.3. Flax grown for fibre

Basic data of the cultivation of flax grown for fibre can be found in *Table 51*.

2.5.4. Test your knowledge

Describe the importance and quality of hemp/tobacco

Describe the botanical characteristics of hemp/tobacco

Describe the environmental requirements of hemp/tobacco

Describe the main aspects of cultivation of hemp/tobacco

Give the sowing data of hemp

Describe the seedling growing and transplanting of tobacco

List the diseases and pests of hemp/tobacco

Describe the harvesting and storage of hemp/tobacco

2.6. PERENNIAL FORAGE LEGUMES

2.6.1. Alfalfa or lucerne (*Medicago sativa* L., *Medicago varia* Martyn)

Alfalfa is the most valuable, protein-rich forage legume which has a broad spectrum of utilization possibilities. It has a positive effect on soil fertility (draining and aggregate forming effect of root system, enriching in N etc.).

Botanical characteristics

Alfalfa is a widely grown perennial legume with a woody yet narrow crown, tap roots and flowers borne on racemes or spikes in various shades of blue, purple, cream and white. Pods range in shape from sickle to spiraled with one or more coils. Leaflets are 9.5 mm to 3.2 cm long, obovate and sharply toothed towards the apex. Traditional varieties are trifoliate, however an increasing number of multifoliolate varieties have been developed. The erect stems usually reach 30 to 90 cm (*Figure 33*).



Figure 33 Alfalfa

Phenological growth stages of alfalfa:

Vegetative phase

- | | |
|---------------------|---|
| 0 Early vegetative: | Stem length ≤ 15 cm, no buds, flowers, or seedpods |
| 1 Mid-vegetative: | Stem length 16-30 cm, no buds, flowers or seedpods |
| 2 Late vegetative | Stem length ≥ 31 cm, no buds, flowers or seedpods |

Flower bud development

- | | |
|--------------|--|
| 3 Early bud: | 1-2 nodes with buds, no flowers or seedpods |
| 4 Late bud: | ≥ 3 nodes with buds, no flowers or seedpods |

Flowering phase

- | | |
|-----------------|---|
| 5 Early flower: | node with 1 open flower, no seedpods |
| 6 Late flower: | ≥ 2 nodes with open flowers, no seedpods |

Seed production

- | | |
|------------------|---|
| 7 Early seedpod: | 3 nodes with green seedpods |
| 8 Late seedpod: | ≥ 4 nodes with green seedpods |
| 9 Ripe seedpod: | Nodes with mostly brown mature seedpods |

Alfalfa is 85-95% open-pollinating, fertilized primarily by wild bees.

Its primary center of origin is the region east from Kaspian Sea, the secondary being the Mediterranean. Alfalfa and all other legumes belong to the family Fabaceae/Leguminosae. Cultivated alfalfa is tetraploid ($2n=4x=32$), its wild relatives are diploid ($2n=16$).

Environmental requirements

Alfalfa tolerates relatively well climate extremities. It is winter-hardy ($-25\text{ }^{\circ}\text{C}$ without snow-cover). Minimum temperature for germination is $2-3\text{ }^{\circ}\text{C}$. To achieve high yields it requires 600-800 mm precipitation (or supplement by irrigation).

Alfalfa does best on semi-cohesive soils with a pH of 6.5 or above, containing a high level of plant nutrients. Alfalfa is sensitive to excess soil water or the lack of good aeration. Surface water should not be allowed to stand more than 2-4 hours during hot weather or 48 hours during lower temperatures.

Physiological stresses that may affect alfalfa plant appearance: soil pH outside of neutral range, poor drainage and limited moisture (particularly tap rooted types).

Cultivation

Small grain cereals (winter wheat and barley, spring barley) harvested prior to mid-July are the best forecrops. Legumes must be avoided. Rotation should not be shorter than 3-4 years.

Alfalfa requires a deeply cultivated root zone. A perfect seedbed should be firm to reduce air pockets, fine to obtain an even covering of seed, level with no places where water stands, and free from weeds that compete with seedlings for moisture and plant nutrients. Basic fertilization and sowing data can be found in *Tables 56* and *57*, respectively.

Table 56 Nutrient requirement of alfalfa

Nutrient uptake by 1 ton of hay				
N: 27 kg/t	P ₂ O ₅ : 7 kg/t	K ₂ O: 15 kg/t	CaO: 35 kg/t	MgO: 3 kg/t

Primarily, establishing without cover crops is recommended.

Cover crops can be useful in exceptional cases such as in fields threatened by erosion or deflation or if established as pasture.

Recommended grass species:

- dry conditions: smooth brome (*Bromus inermis*), orchardgrass (*Dactylis glomerata*)
- soils of good water management, irrigation: meadow-fescue (*Festuca pratensis*), timothy-grass (*Phleum pratense*), perennial ryegrass (*Lolium perenne*)

Table 57 Sowing data of alfalfa

Sowing date:	10. March-10. April	10-25. August
Row distance:	12 cm or broadcasting	
Sowing depth:	1-2 cm (on loose soil 2-3 cm)	
Seed rate		
- 12 cm	12 million seeds/ha	13 million seeds/ha
- broadcasting	6-7 million seeds/ha	7-8 million seeds/ha
With cover crop		
- spring barley	3 million seeds/ha	
- pea	6-7 million seeds/ha	
- grasses	5-6 million seeds/ha	6-7 million seeds/ha
1000 seed weight	2.0-2.4 g	

Alfalfa is drought-tolerant, using up to 70% of available soil water without undue stress or loss of production; if stressed beyond this limit, it will merely stop growing until soil water is available. There are limits, but plants recover from extremely dry periods. Production suffers, but the crop survives. Alfalfa can be a good crop for irrigators with limited water supplies.

Irrigation is most effective in the 1-2. years, at 10-15 cm aftermath. A possible irrigation order: 2. aftermath: 50-70 mm, 3. aftermath: 70-80 mm, 4. aftermath: 50-60 mm, 5. aftermath: 40-50 mm, out of season: 60-80 mm, total: 200-250 (300) mm/season.

Diseases

Fusarium wilt (*Fusarium oxysporum* f.sp. *medicaginis*), Verticillium wilt (*Verticillium albo-atrum*), Phytophthora root rot (*Phytophthora megasperma* f.sp. *medicaginis*), Aphanomyces root rot (*Aphanomyces euteiches*), Crown and root rot complex (*Fusarium* spp. and *Rhizoctonia solani*), damping-off (*Pythium* spp., *Phytophthora megasperma* and *Rhizoctonia solani*), Anthracnose (*Colletotrichum trifolii*), spring blackstem (*Phoma medicaginis*), summer blackstem (*Cercospora medicaginis*), Common leaf spot (*Pseudopeziza medicaginis*), downy mildew (*Peronospora trifoliorum*), Rust (*Uromyces striatus*), bacterial leaf spot (*Xanthomonas campestris* pv. *alfalfae*), alfalfa mosaic virus (AMV), stem nematode (*Ditylenchus dipsaci*)

Pests

Weevils (*Sitonia ssp.*), alfalfa weevil (*Phytonomus variabilis*), darkling beetle (*Opatrum sabulosum*), lucerne beetle (*Phytodecta fornicata*), alfalfa ladybird (*Subcoccinella vigintiquatorpunctata*), alfalfa snout beetle (*Otiorrhynchus ligustici*), alfalfa plant bug (*Adelphocoris lineolatus*), lucerne flower midge (*Contarinia medicaginis*), cotton bollworm (*Helicoverpa armigera*), lucerne seed weevil (*Tichius flavus*), alfalfa seed chalcid (*Bruchophagus roddi*)

Harvesting

Green forage Usually it requires short wilting prior to be given to livestock. Quality depends on the phonological phase of alfalfa.

Hay It is the oldest method of conservation. In the course of the drying process, from the green material of 78-82% moisture content hay of 84% dry matter content will be produced. If dried on the field, main sources of loss are the falling of leaves and the decrease in β -carotene content.

Alfalfa flour (green flour) This conservation method preserves the green material quality the best. Direct-cut green material is dried at 700-900 °C to 90% dry matter content, followed by grinding. If cut and wilted in the field, material of 70% moisture content goes to the dryer.

Conservation by fermentation (alfalfa silage and haylage) Alfalfa is hard to be fermented (high protein content, building of lots of alkalic intermediar compounds etc.).

Alfalfa silage Chop size of 2.5 mm is optimal, initial moisture content of chopped green material is 78-82%. Additives (e.g. corn semolina, artificial compounds) can be applied to help fermentation.

Alfalfa haylage In general, cut green material is let be wilted (40-50% dry matter) in the field prior to chopping and fermenting.

Main aspects for planning the cutting order:

- The two cuts of spring-sown alfalfa cultivated without irrigation are best for hay preparation in the first year. From the next year on, first cuts must be harvested before lodging starts, indepent from the development stage. First cut gives the highest

percentage (35-50%) of the yearly yield. For hay-making summer cuts are the best, especially those harvested at flowering. The time period between harvests usually ranges from 30 to 40 days. In the last year of culture, when feeding is the primary aspect, harvesting dates and conservation methods can be chosen freely. In irrigated cultivation systems, there is a shorter period between cuts. On the other hand, giving out 60-80 mm water requires reasonable time.

- The yield and the quality change according to the phenological phase. Highest yield can be achieved at the green bud – flower bud phase but best quality is reached prior to this phase. On the border of these phases can be found the balanced stage when the worsening feeding quality is compensated by the increasing yield, and the highest amount of crude protein, β -carotene and minerals can be harvested (*Table 58*).
- In the second and succeeding seasons, the first harvest may be taken in the full bud stage, with other harvests being made at 10 percent bloom or before crown buds advance. The last growth must be allowed to grow and store the full amount of food reserves in the tap root before being killed by freezing temperatures. This provides the energy for the new plants to grow the following spring. Usually the last cut should be made no later than mid-September to mid-October. After complete killed by cold, the remaining frosted growth may be removed by harvesting or grazing.

Table 58 Composition of alfalfa depending on developmental stage

	Chemical composition in dry matter							
	Crude protein	Crude fat	Crude fibre	N-free extract	Crude ash	Ca	P	Dry matter
	g/kg							
Sprout	261	39	169	386	145	18.6	3.8	172
Young	235	30	233	380	122	17.8	3.6	215
Budding	204	29	279	371	117	16.8	3.5	228
Flowering	179	27	328	378	88	16.2	3.4	254

2.6.2. White clover (*Trifolium repens* L.)

White clover is primarily the component of grass-containing mixtures in the forage production on arable fields. It is useful for pasture, it withstands continuous grazing. Pure seeding is specifically for seed production purposes. In several regions it is utilized as greenmanure, too. It is easy to establish and has a good tolerance to wide pH range. Its yield as green forage is 3-7 t/ha/year.

There two variety groups according to utilization:

- Type 1: for establishing meadows and pastures or for overseeding, perennial, good winter hardiness, big mass with other components of the grassland
- Type 2: for intensive systems, leafy, tall-growing type, producing high green mass (e.g. Ladino)

Botanical characteristics

White clover is a short to long lived perennial with a shallow tap root system and very small crowns. The primary stems are short with many internodes. Its flowers are usually white, though occasionally they are tinged with pink. The flowers of white clover are borne on peduncles that are somewhat longer than the petioles. There are 20 to 150 florets per head. Each leaf has 3 leaflets, and each leaflet usually has a v-shaped white mark in its centre. The leaflets are usually elliptical to heart shaped. The seeds of white clover are

small and yellow. Its stems are glabrous, have a prostrate growth habit, and grows to 30 to 45 cm tall. The stolon of white clover is solid. The species is highly polymorphic resulting in a great deal of variation in plant and plant part size (*Figure 34*). Ladino is a large form of white clover.

Its primary center of origin is the Mediterranean region. White clover is tetraploid ($2n=4x=32$) and self-incompatible.

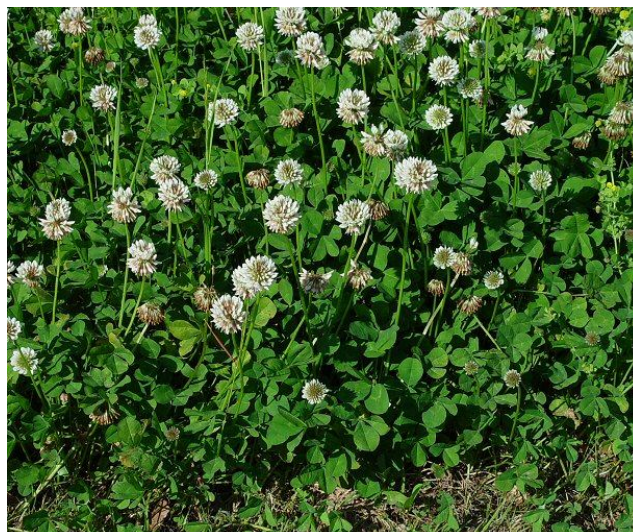


Figure 34 White clover

Environmental requirements

It prefers humid climate (600 mm precipitation per year). It is the crop of cohesive and semi-cohesive soils.

Table 59 Nutrient requirement of white clover

Nutrient uptake to 1 ton of seed yield				
N: 23 kg/t	P ₂ O ₅ : 16 kg/t	K ₂ O: 20 kg/t	CaO: 18 kg/t	MgO: 5 kg/t

Cultivation

Best forecrops are the manured row crops. Legumes and itself (3-4 years) should be avoided as forecrop. It needs irrigation under arid conditions (after the first cuts each year). Basic fertilization and sowing data can be found in *Tables 59* and *60*, respectively.

Table 60 Sowing data of white clover

	White clover	Ladino white clover
Sowing date	10-20. March	1-20. March
Row distance: - with cover crop	24 cm 12 cm	24 cm -
Sowing depth:	1-2.5 cm	1 cm
Seed rate:	10 million /ha 240 seeds/m of row 3.5-8.8 kg/ha	8 million/ha 100 seeds/m of row 3.5-8.8 kg/ha
1000 seed weight:	0.4-0.8 g	0.6-0.7 g

Harvesting

In the first year it can be utilized as green forage. From the second year seed can also be harvested (*Table 61*).

Table 61 Quality of white clover

	Dry matter (%)	Crude protein	Crude fat	Crude fibre
		in the % of dry matter		
Green forage				
- beginning of flowering	19.5	20.5	4.6	27.6
- end of flowering	23.0	10.4	2.2	32.2
Hay				
- full flowering	86.5	17.3	4.0	27.7

2.6.3. Birdsfoot trefoil (*Lotus corniculatus* L.)

Birdsfoot trefoil is a versatile forage legume. It is a regular component of meadows and pastures. On arable lands it is used as green forage or hay for ruminants.

In grassland mixes, its percentage is between 5-50%. In higher rates it can be established under favorable (humid) conditions with non-aggressive accompanying plants (e.g. Kentucky bluegrass - *Poa pratensis*, Timothy grass - *Phleum pratense*) together.

It can be mown once a year in the course of 4-6 years. Depending on the area and soil type, its yield varies between 0.8-3.0 t hay/ha.



Figure 35 Birdsfoot trefoil

Botanical characteristics

Birdsfoot trefoil is a perennial forage with a strong, well-developed tap root system with many branches once mature. It has several stems arising from the rootcrown. The slender and moderately leafy stems are usually 60 to 90 cm in height, and thinner and more flexible than those of alfalfa. Its compound leaflets close over the petiole and stem in darkness. The flowers of birdsfoot trefoil vary from light to dark yellow in colour, with four

to eight florets. Multiple seed pods that attach to the stem at right angles give it the appearance of a bird's foot. Birdsfoot trefoil pods are long and cylindrical, which turn brown to black and maturity (*Figure 35*).

Its primary center of origin is the Mediterranean region. White clover is tetraploid ($2n=4x=24$) and outcrossing.

Environmental requirements

Birdsfoot trefoil prefers humid climate. It can be grown under dryer conditions as well, but this case irrigation is required to achieve an acceptable yield. Primarily, it is grown on acidic soils, on soils of shallow fertile layer and on sandy soils.

Cultivation

It does not have specific preferences regarding forecrops. It is undemanding regarding root layer, but it requires a compact, homogenous seedbed of granular structure. Basic fertilization and sowing data can be found in *Tables 62* and *63*, respectively.

Table 62 Nutrient requirement of birdsfoot trefoil

Nutrient uptake to 1 ton of hay yield				
N: 22 kg/t	P ₂ O ₅ : 8 kg/t	K ₂ O: 17 kg/t	CaO: 15 kg/t	MgO: 2 kg/t

Table 63 Sowing data of birdsfoot trefoil

Sowing date: - spring - summer	10-25. March (30. April) 10-25. August (humid areas or irrigation)
Row distance:	12 cm or broadcasting
Sowing depth:	1-3 cm
Seed rate:	12-13 million/ha (12 cm) 6-8 million/ha (broadcasting) 12-16 kg/ha
1000 seed weight:	1-1.3 g

Harvesting

In the first year it can be mown at flowering in September. From the second year it can be harvested once a year, at the beginning of flowering, at the end of May or beginning of June. Aftermath is suitable for grazing.

2.6.4. Kidney vetch (*Anthyllis vulneraria* L.)

Kidney vetch is a relatively young domesticated crop – its growing started in the 19. century in Germany. It provides valuable feed even in areas where other legumes do not provide acceptable yield.

Because of its bitter taste and hairy surface, the majority of livestock does not like it as green forage, excepting sheep. As hay, it is a tasty feed but it must be gradually introduced. It is a useful cover crop and green manure. Its yield is 3-8 t hay/ha

Botanical characteristics

Kidney vetch has a simple or branched stem, reaching 5–40 centimetres of height. The leaves are imparipinnate, glabrous or with scattered hairs on the upper face and silky hairs on the underside. The flower heads are spherical in shape and 10–20 millimetres long. Its flowers are yellow (*Figure 36*).

Its primary center of origin is the Mediterranean region (Italy). Kidney vetch is diploid ($2n=12$).



Figure 36 Kidney vetch

Environmental requirements

It prefers humid climate and hardly tolerates dry conditions after the harvesting of the cover crop. It is winter hardy. It tolerates extensive conditions very well, but does not bear neglected environment due to pests and weeds.

It is the crop of slope and hilly areas of shallow fertile layer and that of loose sand. On better soils it is not competitive with red clover or sainfoin.

Table 64 Nutrient requirement of kidney vetch

Nutrient uptake to 1 ton of hay yield				
N: 23 kg/t	P ₂ O ₅ : 7 kg/t	K ₂ O: 18 kg/t	CaO: 21 kg/t	MgO: 6 kg/t

Table 65 Sowing data of kidney vetch

Sowing date:	05. March-20. April
Row distance:	12 cm
Sowing depth:	2-3 cm
Seed rate:	8 million/ha 18-20 kg/ha
1000 seed weight:	2.3-2.5 g

Cultivation

It tolerates establishment with cover crops. Except for legumes, each crop is suitable as forecrop. Possibly, it should be rye or triticale. Basic fertilization and sowing data can be found in *Tables 64* and *65*, respectively.

Harvesting

Stems become woody by the end of flowering thus mowing must be performed prior to this stage. It should not be cut too early, either, because of the high bitter compound content of young green plants.

Its nutritional value is 75-85% of that of red clover. It is slightly bitter due to tannin and saponin content. After acclimatization, it can be fed to sheep and beef. It contains 8.6% crude protein and 26.7-32.9% crude fibre.

2.6.5. Sainfoin and crown vetch

Basic data of the cultivation of sainfoin and crown vetch can be found in *Table 66*.

2.6.6. Test your knowledge

Describe the importance and quality of alfalfa/white clover/birdsfoot trefoil/kidney vetch

Describe the botanical characteristics of alfalfa/white clover/birdsfoot trefoil/kidney vetch

Describe the environmental requirements of alfalfa/white clover/birdsfoot trefoil/kidney vetch

Describe the main aspects of cultivation of alfalfa/white clover/birdsfoot trefoil/kidney vetch

Give the sowing data of alfalfa/white clover/birdsfoot trefoil/kidney vetch

List the diseases and pests of alfalfa/white clover/birdsfoot trefoil/kidney vetch

Describe the harvesting and storage of alfalfa/white clover/birdsfoot trefoil/kidney vetch

Table 66 Basic data of the cultivation of some perennial and biannual legumes

Perennial legumes		Biannual legumes	
	Sainfoin (<i>Onobrychis viciaefolia</i> Scop.) 2n=28	Crown vetch (<i>Coronilla varia</i> L.) 2n=24	White sweetclover (<i>Melilotus albus</i> Medik.) 2n=16
Features			
	<ul style="list-style-type: none"> - non-demanding thus optimal for utilization of remediated areas, alkali soils, eroded soils, slopes - composition similar to alfalfa - non-bloating legume - improves the taste and aroma of milk - improves soil fertility - drought and frost tolerant 	<ul style="list-style-type: none"> - has better quality than alfalfa - increases meat and milk production in ruminants - used as hay, haylage or by grazing - non-bloating - drought and frost tolerant - cultivated also on alkali soils - in defence against erosion 	<ul style="list-style-type: none"> - coumarin-free varieties can be used for green forage, hay or silage - can be used for pasture - used as a soil-improving, plowdown crop - adapted to a wide range of soil and climatic conditions - deep-rooted and winter-hardy (the winter following seeding) - opens up subsoil - excellent for bees - not adapted to acid soils, requires calcareous sandy soils
Nutrient supply (kg/ha)			
N:	100+40	40-60	40-60
P ₂ O ₅ :	180-200	150-240	100
K ₂ O:	200-260	120-160	160
Data of sowing			
Date:	5. March-20. April	25. April-10. May	spring: 15-31. March summer: 10-25. August
Row distance:	12 cm	20-24 cm	12 cm or broadcasting
Sowing depth:	2-3 cm	1-2 cm	1-2 cm
Seed rate:	8 million/ha 18-20 kg/ha	2.5-3.5 million/ha 10-17 kg/ha	10 million/ha
1000 seed weight:	2.3-2.5 g	5-6 g	1.9-2.2 g
Harvesting			
	<p>1. year: autumn; full flowering from 2. year:</p> <p>1. cut: 20. May-10. June, early flowering 2. cut: end of August-mid-September (also grazing) Hay: 2-8 t/ha/year</p>	<ul style="list-style-type: none"> - suitable only for ruminants due to containing glucosides - grazing or green foraging: first harvest early - good conditions: 3 harvests/year (60:20:20%) - generally: 2 harvests/year (80:20%) - for hay: first decade of June, at 10% flowering Green mass: 10 t/ha/year, hay: 6-9 t/ha/year 	<p>1. year: late August – early September, before flowering 2. year: 2x Hay: 6-12 t/ha</p>

2.7. BIENNIAL FORAGE LEGUMES

2.7.1. Red clover (*Trifolium pratense* L.)

Red clover is a short-lived perennial which is grown for forage and is used in rotations for soil improvement. It is adapted to areas with moderate summer temperatures and adequate moisture throughout the growing season. Unlike alfalfa, red clover will grow moderately well in slightly acid soils. However, maximum yields are obtained when soil pH is 6.0 or higher. Red clover, a short-lived perennial, usually produces two or three hay crops per year. It is characterized by rapid spring growth and low winter hardiness, which contributes to its short-lived nature.

Botanical characteristics

Two types of red clover exist: single and double cut. Single cut varieties are diploid ($2n = 14$) and tend to be smaller and later-flowering than the double cut varieties. Double cut varieties are tetraploid ($2n = 28$). It has a taproot system as well as many secondary branches. Red clover plants are composed of numerous leafy stems arising from a crown. Each leaf is made up of three oblong leaflets usually bearing a characteristic reddish, inverted V leaf markings in the centre of each leaflet. The heads are compact clusters of up to 125 flowers. Under favourable conditions, these flowers are 9 to 10.5 mm long. Flower colour varies from magenta to pale pink (*Figure 37*).



Figure 37 Red clover

Environmental requirements

Its over-wintering ability is good, however, the periodical change of freezing and melting in the winter can cause root damage. It prefers moderately warm climate. In comparison to alfalfa, red clover is far less drought tolerant, but it is less demanding regarding soil quality.

Cultivation

Soil tests are required for proper determination of soil nutrient availability. In soils with a pH below 6.0, adding lime is essential to make the soil less acidic and improve red clover's nitrogen-fixing activity. Nutrients should be added to the soil on the basis of a soil test. Starter fertilizer applications up to 23-69-23 kilograms per hectare may benefit red clover seedlings. Soil test recommendations that exceed this amount should be incorporated into

the seedbed prior to planting. Red clover should be top dressed annually with fertilizer as long as the plant numbers are sufficient for economic production. When the red clover makes up less than 30 percent of the clover-grass mix, apply 34 or 57 kilograms of N per hectare on sandy or clay soils, respectively. Basic fertilization and sowing data can be found in *Tables 67* and *68*, respectively.

Under dry conditions irrigation is essential to maintain red clover. Irrigation should be applied after each mowing by a dosage of 50-60 mm water.

Table 67 Nutrient requirement of red clover

Nutrient uptake to 1 ton of hay yield				
N: 23 kg/t	P ₂ O ₅ : 5 kg/t	K ₂ O: 20 kg/t	CaO: 25 kg/t	MgO: 5 kg/t

Diseases

Seed mold (*Alternaria alternata*), seed rot and damping-off (*Pythium debaryanum*), Fusarium root rot (*Fusarium spp.*), clover crown and root rot (*Sclerotinia trifolorum*), downy mildew (*Peronospora trifoliorum*), *Verticillium albo-atrum*, summer black stem (*Cercospora zebrina*), common leaf spot (*Pseudopeziza trifolii*), powdery mildew (*Erysiphe communis* f. *trifolii*), clover rust (*Uromyces minor*), anthracnose (*Colletotrichum trifolii*), anther mold (*Botrytis anthophila*), alfalfa mosaic virus (AMV), bean yellow mosaic virus (BYMV), bean mosaic virus (BMV)

Pests

Ditylenchus destructor, *D. dipsaci*, *Heterodera goettingiana*, *H. trifolii*, *Sitona spp.*, *Tanimecus spp.*, *Phytonomus spp.*, *Apion seniculum*, *A. trifolii*, *A. apricans*, *A. virens*, *Discestra trifolii*, *Subcoccinella vigintiquatorpunctata*

Table 68 Sowing data of red clover

Sowing date: - spring - summer	1. March-15. April (also mixed with barley or grasses) 1-20. August
Row distance:	12 cm or 2 row red clover + 2 row grass
Sowing depth:	1-2 cm
Seed rate: - pure - with spring barley - with grasses	8-9 million/ha 20-25 kg/ha 10 million/ha + 2.5 million/ha spring barley 12 million/ha + 10-15 million/ha grasses (Italian ryegrass or timothy grass)
1000 seed weight:	1.4-1.9 g diploid 2.5-2.8 g tetraploid
Productive plants: 1. year 2. year	4 million plants/ha 2 million plants/ha

Harvesting

Red clover quality is comparable with alfalfa quality under similar harvest schedules. However, intake by the consuming animal is generally greater for alfalfa than red clover. Red clover quality does not decline as rapidly with maturity as does alfalfa quality (*Table 69*). This means a longer period over which high-quality forage can be harvested. Spring-seeded red clover can be harvested three times during the seeding year if growing conditions are favorable. This more aggressive harvest management in the seeding year than has traditionally been implemented provides greater forage and nutrient yields and has not negatively affected yield in the year after establishment. In addition, the third harvest during early September will help maintain better stands the following harvest season. Initial harvest 60–70 days after seeding and subsequent harvest on a 30 to 35 day interval will generally allow for three harvests during the seeding year. Established red clover stands should be harvested at prebloom or early bloom. This harvest timing is a compromise between red clover yield and quality. Red clover silage, if properly harvested and stored, provides a high-quality forage. However, red clover is more difficult to cure for hay than other legumes. Establishing with a forage grass will decrease red clover's curing time.

Table 69 Yield and quality of alfalfa and red clover under a two and three-harvest schedule

Species	No. of cuts	Yield t/ha	Crude protein %	Digestible dry matter %
Red clover	2	11.0	14.6	68.3
	3	8.5	21.3	73.3
Alfalfa	2	10.4	15.6	63.4
	3	10.9	20.7	65.2

Source: Smith, *Agronomy Journal* 57: 463–465.

2.7.2. White sweetclover

Basic data of the cultivation of white sweetclover can be found in *Table 66*.

2.7.3. Test your knowledge

- Describe the importance and quality of red clover
- Describe the botanical characteristics of red clover
- Describe the environmental requirements of red clover
- Describe the main aspects of cultivation of red clover
- Give the sowing data of red clover
- List the diseases and pests of red clover
- Describe the harvesting and storage of red clover

2.8. ANNUAL FORAGE LEGUMES

2.8.1. Egyptian (berseem) clover (*Trifolium alexandrinum* Jusl.)

A fast-growing summer annual, berseem clover can produce up to 8 tons of forage (under irrigation). It's a heavy N producer and the least winter hardy of all true annual clovers. This makes it an ideal winterkilled cover before corn or other nitrogen-demanding crops in rotations. It can suppress weeds, prevent erosion, and can be utilized as green manure, chopped forage or by grazing. Egyptian clover is not as drought-tolerant as alfalfa. Some cultivars can tolerate more soil moisture (but not waterlogging) than alfalfa or sweet clover. Winterkilled berseem allows for earlier spring planting than winter-hardy annuals. As dead organic mulch, it poses no moisture depletion risk, but may slow soil warming and drying compared to erosion-prone bare fallow.



Figure 38 Egyptian (berseem) clover

Botanical characteristics

Egyptian clover is a summer annual or winter annual legume, similar in seed size to crimson clover. It has a tap root and a shallow 15 to 20 cm feeder root system. It is bee-friendly because its white or ivory blossoms have no tripping mechanism (*Figure 38*).

Environmental requirements

Berseem prefers slightly alkaline loam and silty soils but grows in all soil types except sands. Soil phosphorus and boron can limit berseem clover growth. Berseem tolerates saline conditions better than alfalfa and red clover.

Cultivation

Basic fertilization and sowing data can be found in *Tables 70* and *71*, respectively. Irrigation can be applied if necessary, to promote germination. Green mass increases if irrigated by 30-35 mm doses.

Table 70 Nutrient requirement of Egyptian clover

Nutrient uptake as green forage to 1 ton of yield				
N: 2.2 kg/t	P ₂ O ₅ : 1.2 kg/t	K ₂ O: 2.4 kg/t	CaO: 2.0 kg/t	MgO: 0.3 kg/t

Table 71 Sowing data of Egyptian clover

Sowing date - main crop - second crop	10-30. April 20-30. July
Row distance:	12 cm or broadcasting
Sowing depth:	1-2 cm
Seed rate:	8 million/ha 5-8 kg/ha
1000 seed weight:	0.7-1.0 g

Harvesting

Cultivated as main crop, first cut can be mown at budding, the second one at full flowering. Last aftermath can be utilized by grazing in September. As second crop, it has one cut only which must be harvested at the end of September, before the frosts. Its root and stubble has an excellent value as green manure.

2.8.2. Crimson clover, fenugreek and French serradella

Basic data of the cultivation of crimson clover, fenugreek and French serradella can be found in *Table 72*.

2.8.3. Test your knowledge

- Describe the importance and quality of Egyptian clover
- Describe the botanical characteristics of Egyptian clover
- Describe the environmental requirements of Egyptian clover
- Describe the main aspects of cultivation of Egyptian clover
- Give the sowing data of Egyptian clover
- List the diseases and pests of Egyptian clover
- Describe the harvesting and storage of Egyptian clover

Table 72 Basic data of the production of some annual legumes

Annual legumes			
	Crimson clover (<i>Trifolium incarnatum</i> L.) 2n=14	Fenugreek (<i>Trigonella foenum-graecum</i> L.) 2n=16	French serradella (<i>Ornithopus sativus</i> Brot.) 2n=14
Features			
	<ul style="list-style-type: none"> - early green forage due to its short growing period - green manure - cultivated pure or as the component of winter forage mixes - poorer quality than red clover - prefers warmer climate but frost tolerant - water demanding 	<ul style="list-style-type: none"> - valuable fodder, herb/drug and spice crop - can be used for hay and silage - nutrition value of seed similar to soybean - green manure, cover crop for soil protection - drought tolerant - no special demands for soil 	<ul style="list-style-type: none"> - useful alternative to lucerne on deep sandy soils where alfalfa is difficult to establish or maintain - not as productive as alfalfa but it is adapted to continuous grazing - on deep acid sands it is more productive than sub clover - it loses its beneficial traits very slowly - tasty green forage - does not cause bloat - improves soil fertility by nitrogen fixation - requires much precipitation - cold and shadow tolerant
Nutrient supply (kg/ha)			
N:	30-40+50 kg/ha	60-80	40-50
P ₂ O ₅ :	50-70	80-120	55-75
K ₂ O:	60-90	100-120	100
Data of sowing			
Date:	spring: 15-30. March summer: 20-30. August	20. March-10. April second crop: July	March
Row distance:	12 cm or broadcasting	12 cm	12 cm or broadcasting
Sowing depth:	1-2.5 cm	2-3 cm	2-3 cm
Seed rate:	9-10 million/ha 30-40 kg/ha	3.8-4.5 million/ha 70-80 kg/ha	2.8-3 million/ha 5-8 kg/ha podded seed (equals to 1-2 kg/ha pure seed)
1000 seed weight:	3.4-4 g	18 g	3-4 g
Harvesting			
	<ul style="list-style-type: none"> - cut green or grazing till the beginning of pollination (May-June) Green: 10-12 t/ha; hay: 2.0-4.2 t/ha 	<ul style="list-style-type: none"> - grain harvesting at 14-15% grain moisture content - harvest of green forage, hay making: 80-90 days after sowing (plant height:50-70 cm) Green: 17-20 t/ha; hay: 4-5 t/ha; seed: 0.6-1.0 t/ha 	<ul style="list-style-type: none"> - cut at the end of June, at full flowering - use as green or fermented - after cut utilized by grazing Green: 8-10 t/ha

2.9. JUICY FODDER CROPS

2.9.1. Fodder beet (*Beta vulgaris* L. ssp. *vulgaris* var. *alba* DC.)

Fodder beet is the highest yielding forage crop. The energy rich fodder beets are complementing the use of grass or protein rich legumes in the diet of the cattle. In many countries fodder beet serves as the reliable winter storage of feed. The yield and forage quality of beets does not vary much from year to year. This brings security and stability in planning - both in field and stable. It can be used for ethanol and energy production, too. Its yield is 40-80 t root/ha.

Botanical characteristics

Fodder beet is a biannual root crop. Its typical root forms can be seen on *Figure 39*.

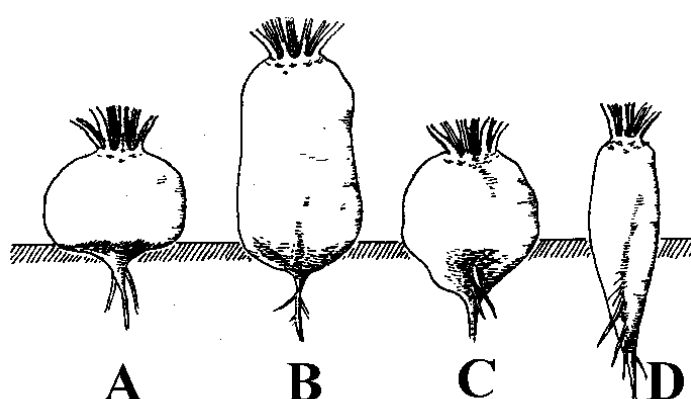


Figure 39 Fodder beet varieties: Flat globe (A), cylinder (B), globe (C), spindle (D)

Environmental requirements

It has high water requirement, 550-600 mm precipitation in the course of the growing period. The good distribution of precipitation in the summer has a yield-determining role. It has a good adaptability to extensive conditions as well. It prefers semi-cohesive loamy Chernozems, Luvisols etc. It requires neutral or slightly alkaline pH.

Table 73 Nutrient requirement of fodder beet

Nutrient uptake of 1 ton of leafy root				
N: 3.7 kg/t	P ₂ O ₅ : 1.7 kg/t	K ₂ O: 5.5 kg/t	CaO: 4.2 kg/t	MgO: 1.2 kg/t

Cultivation

Fodder beet can be cultivated in rotation only. Rotation must be 4 years. It is the best to sow after small grain cereals.

Fodder beet is a deep rooted crop so soil must be well drained and subsoiled to enable the roots to explore water and nutrients throughout the profile. A good seedbed providing fine but firm conditions is essential for a good crop of beet. Basic fertilization and sowing data can be found in *Tables 73* and *74*, respectively.

Irrigation may be necessary to promote germination (10-15 mm), later a regular irrigation (40-60 mm/14-21 days) can be applied.

Table 74 Sowing data of fodder beet

Sowing date:	1-30. April
Row distance:	45 cm
Sowing depth:	2-4 cm
Seed rate:	100,000 seeds/ha 4.5 seeds/m of row
Final plant number:	70,000 plants/ha

Diseases

Root rot (*Pythium debaryanum*, *Aphanomyces laevis*, *Alternaria tenuis*, *Fusarium spp.*, *Rhizoctonia spp.*), ‘black leg’ and Phoma leaf spot disease (*Pleospora /Phoma/ betae*), *Alternaria* leaf spot (*A. tenuis*), bacterial leaf spots (*Pseudomonas syringae*), beet rust (*Uromyces betae*), *Cercospora* leaf spot (*C. beticola*), downy mildew (*Peronospora farinosa*), powdery mildew (*Erysiphe betae*), *Ramularia* leaf spot disease (*R. beticola*), Beet mild yellowing virus (BMV), Necrotic beet yellow virus (BYV), crown-gall disease (*Agrobacterium tumefaciens*), Rhizomania (caused by Beet Necrotic Yellow Vein Virus /BNYVV/, which is introduced and transmitted by the soil fungus *Polymyxa betae*).

Pests

Nematodes (*Ditylenchus spp.*), beet cyst nematode (*Heterodera schachtii*), pygmy beetle (*Atomaria linearis*), wireworm (*Agriotes spp.*), beet flea beetle (*Chaetocnema tibialis*), beet weevil (*Cleonus punctiventris*), beet leaf-weevil (*Lixus scabricollis*), cabbage moth (*Mamestra brassicae*), black bean aphid (*Aphis fabae*), beet carrion beetle (*Blitophaga opaca*, *B. undata*), beet moth (*Scrobipalpa ocellatella*), beet fly (*Pegomyia hyoscyami*)

Harvesting

Medium dry matter varieties tend to have a higher percentage of the root above the ground and can be lifted with a top lifter and have a relatively low dirt tare. These can be fed whole to stock. High dry matter varieties tend to sit further in the ground and require a sugar beet harvester to lift them. Due to the higher dirt tare and hardness of the root, these varieties may need to be chopped and washed before feeding. After wilting, the tops may be fed to stock and can contribute a further yield of 3-4 tons protein rich dry matter per hectare.

2.9.2. Turnip (*Brassica rapa* L. var. *rapa*)

Turnip is a highly nutritious forage crop that has a short growing season and can provide late fall grazing after other forage crops are finished for the year. It is a root Brassica crop which has been used as a vegetable for human consumption since prehistoric times, and its root has been a popular livestock fodder for at least 600 years. It has the potential as pasture as well.

In general, the root Brassicas are fast-growing, high yielding and well adapted to seeding into existing pastures with little or no tillage or to seeding into a conventionally prepared seedbed.

Turnip produces high-quality forage if harvested before heading. Livestock eat the stems, leaves and roots of turnip plants. Above-ground parts normally contain 20-25% crude protein, 65-80% in vitro digestible dry matter (IVDDM), ca. 20% neutral detergent fiber

and ca. 23% acid detergent fiber. The roots contain 10 - 14% crude protein and 80 - 85% IVDDM.

The high levels of glucosinolates can be a problem if turnip forage is fed for long enough. Glucosinolates are higher in older forage.



Figure 40 Turnip

Botanical characteristics

Turnip is a biennial which generally forms seed the second year or even late in the fall in the first year if planted early in the spring. During the first or seeding year 8 to 12 erect leaves, 30 to 35 cm tall are produced per plant. Turnip leaves are usually light green, thin and sparsely pubescent (hairy). In addition, a white-fleshed, large globular or tapered root develops at the base of the leaf petioles. The storage root varies in size but usually is 7.5 to 10 cm wide and 15 to 20 cm long. The storage root can overwinter in areas of mild winter or with adequate snow cover for insulation and produce 8 to 10 leaves from the crown in a broad, low-spreading growth habit the following spring. Branched flowering stems 30 to 90 cm tall are also produced. The flowers are clustered at the top of the raceme and are usually raised above the terminal buds. Turnip flowers are small and have four light-yellow petals (*Figure 40*).

Environmental requirements

Brassicas are both cold-hardy and drought-tolerant. They can be planted late-even as a second crop-and provide high-quality grazing late in the fall. Turnip planted in July will provide grazing from September to November. The most vigorous root growth takes place during periods of low temperature (4.4 to 16 °C) in the fall. The leaves maintain their nutritional quality even after repeated exposure to frost. Turnip grows best in a moderately deep loam, fertile and slightly acid soil. Turnip does not do well in soils that are of high clay texture, wet or poorly drained. For good root growth turnip needs a loose, well aerated soil.

Cultivation

Turnip can be cultivated in rotation only. Early harvested forage crops are the best, e.g. winter barley, forage mixes, green pea, crimson clover.

Turnip seed is small and it is essential that it be seeded into a fine, firm seedbed with adequate moisture for germination. Plough and disk or harrow to produce a seedbed that is

fine, firm and free of weeds and clods. Turnip can also be seeded into a sod or into stubble of another crop with minimum tillage.

Good soil fertility is very important for good yields. Soil tests should be taken to assure proper fertilization. Acid soils should be limed to pH 6.0. Fertilizers should be applied at the time of seeding or within 3 days of seeding to give the crop a competitive edge on weeds. Basic fertilization and sowing data can be found in *Tables 75 and 76*, respectively. Weeds are generally not a problem once the turnip crop is established.

Table 75 Nutrient requirement of turnip

Nutrient uptake of 1 ton of leafy root				
N: 3.2 kg/t	P ₂ O ₅ : 1.5 kg/t	K ₂ O: 3.9 kg/t	CaO: 3.0 kg/t	MgO: 0.6 kg/t

Table 76 Sowing data of turnip

Sowing date:	1-20. July (in the summer until ca. 70 days before a killing frost)
Row distance:	24-36(40) cm 12 cm for grazing
Sowing depth:	2-3 cm
Seed rate:	150,000/ha ca. 0.4 kg/ha
1000 seed weight:	2.5 g

Diseases

Turnip crops may suffer from clubroot, root knot, leaf spot, white rust, scab, anthracnose, turnip mosaic virus and rhizoctonia rot. In some cases, diseases can lead to crop failure if rotation or other control measures are not used. Resistant varieties are available for some diseases. To prevent problems with diseases, Brassicas should not be grown on the same site more than two years in a row. If clubroot is a problem, rotation should be six years.

Pests

Turnip crops are attacked by flea beetles, by common turnip louse or aphid.

Harvesting

Its harvesting can be fractionized, started at the end of September. Normally it is harvested in November when the weight of roots reaches 0.5-0.6 kg. Roots have to be harvested with leaves together. It is suitable for silage making, for example with corn stalk together. Yields of forage turnip range 20-40 tons of leafy root/ha or 7-10 tons of dry matter/hectar when harvested or grazed about 90 days after planting.

Turnip plants are ready for grazing or green-chop when the forage is about 30 cm tall (70 to 90 days after planting). The pasture should be grazed for a short time and the livestock removed to allow the plants to regrow. If grazed, 1 to 4 grazing periods may occur, depending on planting date and growing conditions.

The forage quality of turnip is sufficiently high, especially in protein, it should be considered similar to concentrate feeds, and precautions should be taken to prevent animal health problems. Livestock should not be hungry when put on pasture the first time so they do not gorge themselves.

2.9.3. Fodder kale, fodder carrot, fodder pumpkin, spring rapeseed and turnip rape

Basic data of the cultivation of fodder kale, fodder carrot, fodder pumpkin, spring rapeseed and turnip rape can be found in *Tables 77 and 78*.

2.9.4. Test your knowledge

Describe the importance and quality of fodder beet/turnip

Describe the botanical characteristics of fodder beet/turnip

Describe the environmental requirements of fodder beet/turnip

Describe the main aspects of cultivation of fodder beet/turnip

Give the sowing data of fodder beet/turnip

List the diseases and pests of fodder beet/turnip

Describe the harvesting and storage of fodder beet/turnip

Table 77 Basic data of the production of some juicy fodder crops

	Fodder kale (cow cabbage, collards) (<i>Brassica oleracea</i> L. convar. <i>acephala</i> (DC.) Alef.) 2n=18	Fodder carrot (<i>Daucus carota</i> L.) 2n=18	Fodder pumpkin (<i>Cucurbita pepo</i> L., <i>C. maxima</i> Duch.) 2n=40
Features			
	<ul style="list-style-type: none"> - provides very high yields of succulent green fodder - big advantage: flexible utilisation period from July to the following March - high crude protein content - fed for all types of livestock - ideal full season gamecover crop - good adaptability - high water consumption - no special soil demand - requires rotation of 4 years 	<ul style="list-style-type: none"> - high carotene content - moderately storable as juicy fodder - important additional feed for horses - good storability sliced and dried - moderate temperature and water requirement - good adaptability 	<ul style="list-style-type: none"> - traditionally grown between the rows of corn - primarily utilized during the drought period in August - low nutrition value (94-95% water content) - for pigs, dairy cows, horses - varieties rich in carotene are beneficial for lactation - if given to poultry, cannibalism and feather pecking stop - requires heat, light and water - rotation is 5 years
Nutrient supply (kg/ha)			
N:	100-120	40-300	(60 in manure) 75-100
P ₂ O ₅ :	80-100	20-120	(60 in manure) 100-140
K ₂ O:	120-150	50-350	(160 in manure) 120-160
Data of sowing			
Main crop:	March (15-30. April)	10. March-15. April	25. April-10. May
Second crop:	June (1-15. July)	till 10. July	
Row distance:	60-75 cm	36-40 cm 45 + 6 cm twin-row	70 – 90 cm (bushy) 120-140 cm (indeterminate)
Sowing depth:	1-1.5 cm	1-3 cm	4-5 cm
Seed rate:	500,000 seeds/ha 35 seeds/m of row	5 million seeds/ha 35 seeds/m of row productive. 200-280,000 plants/ha 5-5.5 kg/ha	18-20,000/ha (bushy) 15-17,000/ha (indeterminate) 12-15 seeds/m
1000 seed weight:	2-4 g	2-2.5 g	300-500 g
Harvesting			
	<ul style="list-style-type: none"> - harvesting of lower leaves by hand during the whole growing period - cutting, chopping for green forage from mid-September - suitable for silage making (e.g. with maize stem together) and grazing Yield: 10-100 t/ha 	<ul style="list-style-type: none"> - see fodder beet for harvest - storage maximum till the end of December with 1-2 cm leaf residue Yield: 5-80 t root/ha 	<ul style="list-style-type: none"> - ripening from the end of August Yield: 20-80 t/ha

Table 78 Basic data of the production of some juicy fodder crops (continued)

	Spring rapeseed (<i>Brassica napus</i> L. var. <i>annuus</i>) 2n=38	Turnip rape (<i>Brassica rapa</i> L. subsp. <i>oleifera</i>) 2n=20
Features		
	<ul style="list-style-type: none"> - non-demanding thus optimal for good adaptability - valuable forage for dairy cattle - excellent as green manure - prefers cool, moderately warm areas free of hard frost - rotation is 3-4 years 	<ul style="list-style-type: none"> - short growing season - occasionally overwintering - can be mown or grazed - excellent for cows and sheep - can be utilized as green maure - prefers moderately warm, humid conditions
Nutrient supply (kg/ha)		
N:	60-110	25-100
P ₂ O ₅ :	30-50	20-60
K ₂ O:	70-120	40-120
Data of sowing		
Main crop:	10. March-15. April	1-10. March
Second crop:	10. July-10. August	1-31. July
Row distance:	12 cm	24 cm
Sowing depth:	1-2 cm	2 cm
Seed rate:	2.2 million seeds/ha 30 seeds/m of row productive: 1.2 million plants/ha 10-12 kg/ha	1 million seeds/ha 24 seeds/m productive: 500-00,000 plants/ha 5-6 kg/ha
1000 seed weight:	4-6 g	5-6 g
Harvesting		
	<ul style="list-style-type: none"> - cut green for forage or silage - at early developmental stage suitable for grazing Yield: 5-40 t green mass/ha 	<ul style="list-style-type: none"> - can be mown or grazed - as second crop it can be cut once - after overwintering cut early (can cause taste anomalies in milk) Yield: 10-40 t green mass/ha (2 or 3 cuts)

2.10. SUCCESSION PLANTING

Succession planting refers to several planting methods that increase crop availability during a growing season by making efficient use of space and timing. There are four basic approaches that can also be combined:

- Two or more crops in succession: After one crop is harvested, another is planted in the same space. The length of the growing season, climate, and crop selection are key factors. For example, a cool season spring crop could be followed by a heat-loving summer crop.
- Same crop, successive plantings: Several smaller plantings are made at timed intervals, rather than all at once. The plants mature at staggered dates, establishing a continuous harvest over an extended period (e.g. lettuce).
- Two or more crops simultaneously: Non-competing crops, often with different maturity dates, are planted together in various patterns (e.g. intercropping and companion planting).
- Same crop, different maturity dates: Several varieties are selected, with different maturity dates: early, main season, late. Planted at the same time, the varieties mature one after the other over the season.

Catch cropping is a type of succession planting. Catch crop is a fast-growing crop that is grown simultaneously with (grown between rows, harvested before main crop), or between successive plantings of a main crop (between spring harvest and fall planting). It makes more efficient use of growing space (*Table 79*).

Table 79 Forage catch crops

	Sowing date	Seed/ha	Green mass t/ha	Harvesting
Fodder rape	1. June -10. August	2,000,000	10-25	from 1. August
Sudangrass	5. June-10. July	1,500,000	15-30	from 10. August
Pea - fodder rape forage mix	20. July-10. August	pea 500,000 rape 2,000,000	17-22	from 1. October
Phacelia	1. May-30. July	5,000,000	20-40	from 15. July
Egyptian clover	10-20. July	8,000,000	5-16	from 1. October
Rye - rape forage mix	1-10. August	rye 2,000,000 rape 4,000,000	12-18	from 15. October
Oilseed radish	1-15. August	2,000,000	10-40	from 1. October
White mustard	1-15. August	2,000,000	10-35	from 1. October

2.10.1. Oilseed radish (*Raphanus sativus* L. convar. *oleiferus* (Mill.) Metzger)

Oilseed radish as catch crop is generally planted to improve soil quality for economic crop production. It has the ability to recycle soil nutrients, suppress weeds and pathogens, break up compaction, reduce soil erosion, and produce large amounts of biomass. Freezing temperatures below -8 °C will kill oilseed radish which allows for successful no-till spring planting of subsequent crops. As a fast growing, cool season crop, oilseed radish is best utilized when planted after small grain (e.g. wheat) or corn silage harvest. Depending on soil and growing area, its green mass is 10-40 t/ha.

Botanical characteristics

Oilseed radish has a large, fleshy taproot that can grow 5 to 7.6 centimeters in diameter and 30 cm or more in length. Above ground growth consists of wide leaves that are soft, moist, and fast growing. The foliage reaches 30 to 60 cm in height in a semi-erect stature (*Figure 41*). Leaf stems easily break from the main root, therefore traffic or grazing will destroy plant growth.



Source: Todd Martin (MSU-KBS)

Figure 41 Oilseed radish

Environmental requirements

It can be cultivated in every kind of semi-cohesive chernozems, forest soils and humic sandy soils which are suitable for second plant seeding. It requires little water in the first 2-3 weeks of growing. To get a big amount of green mass, 2-3 days of medium precipitation level are required at the end of August or first half of September.

Table 80 Nutrient requirement of oilseed radish

Nutrient uptake of 1 ton of mown or grazed green product				
N: 2.9 kg/t	P ₂ O ₅ : 1.6 kg/t	K ₂ O: 3.2 kg/t	CaO: 2.8 kg/t	MgO: 0.6 kg/t

Table 81 Sowing data of oilseed radish

Sowing date:	1-15. August (as second crop)
Row distance:	12 cm
Sowing depth:	1-3 cm
Seed rate:	2.6-3.0 million seeds/ha 31-36 seeds/m of row 21-33 kg/ha
1000 seed weight:	8-11 g
Harvested:	1-1.5 million plants/ha

Cultivation

As a cool season crop, oilseed radish is best suited for early fall growth. Opportunities for planting oilseed radish in a cropping system would include: after small grain (e.g. wheat), after vegetable or sweet corn, after corn silage, or after early maturity soybean harvest. Cruciferae species and other early vegetables should be avoided as forecrop. Basic fertilization and sowing data can be found in *Tables 80* and *81*, respectively.

Due to its fast growing ability, oilseed radish is capable of producing large amounts of biomass in a short period of time. Capturing and recycling of excess soil nutrients in biomass is one of the most important features of this cover crop. When planted after manure, sludge, or fertilizer application, oilseed radish may prevent water quality problems by storing nutrients in its biomass. Due to its fleshy composition (and low carbon: nitrogen ratio), the plant material easily decomposes and nutrients become available for the crop planted the following spring.

Seed size is similar to alfalfa; therefore, when using a drill, a small seeder attachment is necessary. Broadcast seeding of oilseed radish can be done successfully if followed by light tillage incorporation.

Utilization

It can be utilized for grazing by sheep, goats, calves and beef from the middle of September. It keeps green till the permanent frosts. Frozen stalks can be grazed by sheep. Oilseed radish may have an allelochemical effect following decomposition that can help control soil-borne pests, including insects, weeds and nematodes.

2.10.2. White mustard (*Sinapis alba* L.)

Similarly to oil radish, white mustard keeps vegetative stage if sown in the first half of August. Depending on soil and growing area, its green mass is 10-35 t/ha. If grown in the same area, on soils of poorer quality the oil radish, on soils of better quality the white mustard gives higher yield.

Botanical characteristics and environmental requirements

Environmental requirements, biological and physiological features are highly similar to those of oilseed radish (*Figure 42*).



Source: SuperJew

Figure 42 White mustard

Cultivation

Small grain cereals are optimal forecrops. Basic fertilization and sowing data can be found in *Tables 82* and *83*, respectively.

Table 82 Nutrient requirement of white mustard

Nutrient uptake of 1 ton of mown or grazed green product				
N: 2.6 kg/t	P ₂ O ₅ : 1.9 kg/t	K ₂ O: 3.7 kg/t	CaO: 2.5 kg/t	MgO: 0.5 kg/t

Table 83 Sowing data of white mustard

Sowing date:	1-15. August (as second crop)
Row distance:	12 cm
Sowing depth:	1-3 cm
Seed rate:	1.8-2.3 million seeds/ha 22-28 seeds/m of row 8-16 kg/ha
1000 seed weight:	4-8 g
Harvested:	1-1.7 million plants/ha

Utilization

It can be utilized for grazing by sheep, goats, calves and beef from the middle of September. Its height is 40-70 cm. Ground frost in fall do not hinder its development, while later it does not survive the longer frosts. Frozen stalks can be grazed by sheep or goats.

2.10.3. Phacelia (*Phacelia tanacetifolia* Benth.)

Phacelia is a versatile plant that is primarily used as bee forage but it is important as forage, ornamental (unusual and attractive blooms, strong stems, long vase-life) and green manure, too. Phacelia is quick to grow and flower and grows well in dry soil. It does a good job of limiting nitrate leaching when planted in early fall. It winterkills at about -8 °C and the residue breaks down quickly. It can be used as second crop in the summer. Phacelia is listed as one of the top 20 honey-producing flowers for honeybees and is also highly attractive to honeybees, bumblebees, and syrphid flies, and these insects are valuable pollinators. It also attracts other beneficial insects, such as parasitic wasps and minute pirate bugs. It provides both pollen and nectar. It can be succession sown so that it is in flower all season or it can be sown at a specific time to build up beneficial insect populations in anticipation of their need to control a crop pest. If there is a large area of phacelia planted, the planting should be timed so that phacelia flowers are not blooming when pollination of another crop is needed. Phacelia's habit of flowering abundantly and for a long period (4-8 weeks) can increase beneficial insect numbers and diversity, because it provides high quality nectar (sugar: 28%) and pollen. Four to six bee families can be settled to 1 ha phacelia, producing more than 800 kg/ha honey.

Botanical characteristics

Phacelia is an herbaceous, non-leguminous, flowering annual in the Hydrophyllaceae family. Height ranges from 15 to 120 centimeters. The foliage appears ferny, and the flowers are in flat-topped clusters in shades of purple or occasionally white (*Figure 43*). Flowering continues for 6 to 8 weeks. Phacelia is a long-day plant and requires a minimum of 13 hours of daylight to initiate flowering. Phacelia is comparable to buckwheat (*Fagopyrum esculentum*) in many ways. Cultural differences are that buckwheat germinates more readily - especially at higher soil temperatures, and phacelia is more tolerant of cold and drought.



Source: Rasbak

Figure 43 Phacelia

Environmental requirements

The optimum soil temperature for germination is between 3 – 20 °C (soil temperatures closely follow air temperatures). It does not require much water during the vegetation period but to achieve high yields, moderately warm, humid climate is needed till flowering. Wet or compacted soils reduce germination success. It requires semi-cohesive Chernozems and Luvisols. It is not suitable for soils of less than 1.2% humus content.

Cultivation

Best forecrops are manured row crops and fibre crops as well as small grain cereals (winter wheat, winter barley). Forecrops susceptible for white mold (e.g. rape, mustard, sunflower, carrot) and monoculture should be avoided. Basic fertilization and sowing data can be found in *Tables 84* and *85*, respectively.

Table 84 Nutrient requirement of phacelia

Nutrient uptake as green forage or green manure:				
N: 2.3 kg/t	P ₂ O ₅ : 1.5 kg/t	K ₂ O: 3.2 kg/t	CaO: 1.0 kg/t	MgO: 0.4 kg/t

Harvesting

Phacelia is suitable for usage as fodder or pasture until the beginning of flowering (*Table 86*).

Its yield is:

- green forage: 20-40 t/ha
- bee pasture – honey: 0.2-0.5 t/ha
- seed (capsule): 0.3-0.5 t/ha

Phacelia has proven its usefulness as a food source for pollinators and other beneficial insects. It has also proven its value as a cover crop – especially when there is a desire to attract beneficial insects.

Table 85 Sowing data of phacelia

Sowing date: - seed - insectary planting - green manure and insectary planting	15-30. March 1-30. April 1. May-30. July (second crop) 10-30. September
Row distance: - fodder - insectary planting and seed	12 cm 24-36 cm
Sowing depth:	2-3 cm
Seed rate:	4.5-5.5 million seeds/ha 30 seeds/m of row 6-10 kg/ha
1000 seed weight:	1.4-1.8 g

Table 86 Chemical composition of phacelia mown at tender stage, dried for hay

	Composition (%)
Dry matter	86.96
Water	13.04
Crude protein	10.93
Crude fat	1.65
Crude fibre	27.75
N-free extract	43.47
Ash	16.20

2.10.4. Test your knowledge

Give the basic aspects of succession planting/catch cropping

Describe the importance and quality of oilseed radish/white mustard/phacelia

Describe the botanical characteristics of oilseed radish/white mustard/phacelia

Describe the environmental requirements of oilseed radish/white mustard/phacelia

Describe the main aspects of cultivation of oilseed radish/white mustard/phacelia

Give the sowing data of oilseed radish/white mustard/phacelia

List the diseases and pests of oilseed radish/white mustard/phacelia

Describe the harvesting and storage of oilseed radish/white mustard/phacelia

2.11. FORAGE MIXES

Forage mixes are grown primarily to provide green forage for ruminants. They are highly important in areas having restricted possibilities for grazing and can be easily inserted into various crop rotation systems. Their production is simple and does not need much energy and investment – it suits for ecological farming systems as well.

In general, best quality can be achieved if harvested prior to full flowering. Depending on the combination, it lasts for 5-7 days. Abundant yield of worsening quality can be conserved as silage or hay.

2.11.1. Winter forage mixes

Basic data on sowing and harvesting of winter forage mixes can be found in *Tables 87-92*.

Table 87 Sowing and harvesting data of the rye and hairy vetch mix

	Rye <i>(Secale cereale)</i>	Hairy vetch <i>(Vicia villosa)</i>
Seed rate:	2 million seeds/ha 24 seeds/m of row	3 million seeds/ha 36 seeds/m of row
1000 seed weight:	30 g	35 g
Sowing date:	5-15. September	
Row distance:	12 cm	
Sowing depth:	3-4 cm	
Harvesting date:	5-15. May	
Yield:	18-25 tons/ha	

Table 88 Sowing and harvesting data of the wheat and Pannon vetch mix

	Wheat <i>(Triticum aestivum)</i>	Pannon vetch <i>(Vicia pannonica)</i>
Seed rate:	3 million seeds/ha 36 seeds/m of row	2 million seeds/ha 24 seeds/m of row
1000 seed weight:	42 g	40 g
Sowing date:	5-15. October	
Row distance:	12 cm	
Sowing depth:	4-5 cm	
Harvesting date:	5-30. May	
Yield:	15-23 tons/ha	

Table 89 Sowing and harvesting data of the rye and rapeseed mix

	Rye <i>(Secale cereale)</i>	Rapeseed <i>(Brassica napus)</i>
Seed rate:	2.5 million seeds/ha 30 seeds/m of row	2 million seeds/ha 24 seeds/m of row
1000 seed weight:	30 g	5 g
Sowing date:	5-15. September	
Row distance:	12 cm	
Sowing depth:	2-4 cm	
Harvesting date:	25. March-20. April	
Yield:	18-25 tons/ha	

Table 90 Sowing and harvesting data of the wheat/rye, hairy vetch and crimson clover mix

	Wheat or rye	Hairy vetch (<i>Vicia villosa</i>)	Crimson clover (<i>Trifolium incarnatum</i>)
Seed rate:	1.5 million seeds/ha 18 seeds/m of row	2.5 million seeds/ha 30 seeds/m of row	5 million seeds/ha 108 seeds/m of row
1000 seed weight:	40 g or 30 g	35 g	4 g
Sowing date:	25. August-10. September		
Row distance:	12 cm		
Sowing depth:	2-3 cm		
Harvesting date:	25. April-20. May		
Yield:	25-30 tons/ha		

Table 91 Sowing and harvesting data of the ryegrass, vetch and clover mix

	Italian ryegrass (<i>Lolium multiflorum</i>)	Hairy vetch (<i>Vicia villosa</i>)	Crimson clover (<i>Trifolium incarnatum</i>)
Seed rate:	5 million seeds/ha 60 seeds/m of row	700,000 seeds/ha 8 seeds/m of row	5 million seeds/ha 128 seeds/m of row
1000 seed weight:	40 g	35 g	4 g
Sowing date:	20. August-30. September		
Row distance:	12 cm		
Sowing depth:	1-2 cm		
Harvesting date:	25. April-20. May		
Yield:	25-30 tons/ha		

Table 92 Sowing and harvesting data of the barley, vetch and pea mix

	Winter barley (<i>Hordeum vulgare</i>)	Pannon vetch (<i>Vicia pannonica</i>)	Winter pea (<i>Pisum sativum</i>)
Seed rate:	2.5 million seeds/ha 30 seeds/m of row	1 million seeds/ha 12 seeds/m of row	200,000 seeds/ha 2-3 seeds/m of row
1000 seed weight:	40 g	40 g	200 g
Sowing date:	15-25. September		
Row distance:	12 cm		
Sowing depth:	3-4 cm		
Harvesting date:	5-20. May		
Yield:	20-26 tons/ha		

2.11.2. Spring forage mixes

Basic data on sowing and harvesting of spring forage mixes can be found in *Tables 93-96*.

Table 93 Sowing and harvesting data of the oat and spring vetch mix

	Oat <i>(Avena sativa)</i>	Spring vetch <i>(Vicia sativa)</i>
Seed rate:	2.5 million seeds/ha 30 seeds/m of row	2 million seeds/ha 24 seeds/m of row
1000 seed weight:	30 g	50 g
Sowing date:	1. March-10. April	
Row distance:	12 cm	
Sowing depth:	3-4 cm	
Harvesting date:	10-30. June	
Yield:	13-20 tons/ha	

Table 94 Sowing and harvesting data of the oat, pea and spring vetch mix

	Oat <i>(Avena sativa)</i>	Forage pea <i>(Pisum sativum)</i>	Spring vetch <i>(Vicia sativa)</i>
Seed rate:	3 million seeds/ha 36 seeds/m of row	500,000 seeds/ha 8 seeds/m of row	1 million seeds/ha 12 seeds/m of row
1000 seed weight:	30 g	200 g	50 g
Sowing date:	10. March-10. April		
Row distance:	12 cm		
Sowing depth:	4 cm		
Harvesting date:	10-30. June		
Yield:	14-18 tons/ha		

Table 95 Sowing and harvesting data of the sunflower and pea mix

	Sunflower <i>(Helianthus annuus)</i>	Forage pea <i>(Pisum sativum)</i>
Seed rate:	400,000 seeds/ha 10 seeds/m of row	600,000 seeds/ha 14 seeds/m of row
1000 seed weight:	100 g	200 g
Sowing date:	20. March-30. April	
Row distance:	24 cm	
Sowing depth:	6-7 cm	
Harvesting date:	1. June-10. July	
Yield:	24-35 tons/ha	

Table 96 Sowing and harvesting data of the maize and pea mix

	Maize (<i>Zea mays</i>)	Forage pea (<i>Pisum sativum</i>)
Seed rate:	400,000 seeds/ha 14 seeds/m of row second crop: halved doses	600,000 seeds/ha 21 seeds/m of row
1000 seed weight:	200 g	200 g
Sowing date:	main crop: 15-30. April second crop: 1. May-15. July	
Row distance:	main crop: 36 cm second crop: 24 cm	
Sowing depth:	6 cm	
Harvesting date:	main crop: 1-20. July second crop: 15. July-20. September	
Yield:	24-38 tons/ha	

2.11.3. Test your knowledge

Describe the basic concept of the cultivation of forage mixes

Give the basic data of cultivation for some important winter/spring mixes

REFERENCES

Alternative Field Crops Manual. University of Wisconsin Cooperative Extension Service, University of Minnesota Extension Service and the Center for Alternative Plant and Animal Products (<https://www.hort.purdue.edu/newcrop/afcm/>)

Antal, J. (ed.), 2005. Crop production 1. Basics of crop production. Cereals (In Hungarian). Mezőgazda Kiadó, Budapest. 392 p.

Antal, J. (ed.), 2005. Crop production 2. Root crops, pulses, oil and other industrial crops, fodder crops (In Hungarian). Mezőgazdasági Kiadó, Budapest. 596 p.

ASAE, S414.1 FEB04 Terminology and Definitions for Agricultural Tillage Implements. ASAE Standards, pp. 270-272.

Barber, R., 2000. Principal tillage methods. In: Manual on integrated soil management and conservation practices. FAO Land and Water Bulletin No. 8. pp. 55-80.

<http://faostat.fao.org/site/567/default.aspx#ancor>

ISAAA Brief 41-2009: Executive Summary. Global Status of Commercialized Biotech/GM Crops: 2009 The first fourteen years, 1996 to 2009. (<http://www.isaaa.org/resources/publications/briefs/41/executivesummary/default.asp>)

Kristó, I., 2008. Investigation of productivity of winter wheat species from Szeged under different cultivation circumstances (In Hungarian). PhD thesis. 151 p.

Meier, U. (ed.), 2001. Growth stages of mono-and dicotyledonous plants. BBCH Monograph. 2. Edition. Federal Biological Research Centre for Agriculture and Forestry, Berlin and Braunschweig. 158 p.

Pepó, P., Sárvári, M., 2011. Production of cereals (In Hungarian). Debreceni Egyetem, Nyugat-Magyarországi Egyetem, Pannon Egyetem. http://www.tankonyvtar.hu/hu/tartalom/tamop425/0010_1A_Book_09_Gabonanovenyek_termesztese/adatok.html

Skinner, R.H., Moore, K.J., 2007. Growth and development of forage plants. In: R.F. Barnes, C.J. Nelson, K.J. Moore and M. Collins (eds.): Forages: The science of grassland agriculture. Blackwell Publishing. Pp. 53-66.

Ujvárosi, M., 1973. Weeds (In Hungarian). Mezőgazdasági Kiadó, Budapest. 833 p.

World Reference Base for Soil Resources 2006

(http://waicent.fao.org/fileadmin/templates/nr/images/resources/pdf_documents/wrb2007_revised.pdf)

Photos were taken by István Kristó and the author, or originate from open web sources. Other sources are marked in the text.

