Chapter

Oilseed Rape: Biology, Use, Current Cultivation Issues and Agronomic Management

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Abstract

Oilseed rape is an economically crucial agricultural crop widely grown in many countries. It is an herbaceous plant which belongs to the *Brassicaceae* family and, according to the nature of vegetation, is present in spring and winter subspecies. Over the years, the area of oilseed rape increased due to its widespread use for producing technical and food oil, fuel and other market needs. Oilseed rape oil is one of the most widely used food oils on the globe. It is valued for its high content of unsaturated fatty acids and odorlessness. The yield of oilseed rape mainly depends on its genetic potential, agronomic management, and environmental conditions. Thus, oilseed rape growers worldwide meet not only common, but also climate zone-specific agronomic issues, e.g., various unfavourable abiotic and biotic factors characteristic to a particular climate zone. Thanks to the efforts of breeders, scientists, and chemical companies, the solutions to the big problems such as disease resistance, lodging, delayed harvest, weed, pest and pod shatter control, are already available and still under search aiming to reveal the full potential of the cultivars.

Keywords: abiotic stress, *Brassica napus*, canola, environmental factors, oil, pests, seeds, weeds

1. Introduction

Oilseed rape (*Brassica napus* L.) is among the oldest crops grown in the world. It belongs to the flowering plant family *Brassicaceae*. This family is also called *Cruciferae* or the mustard family. It includes around 3 thousand plant species. The characteristic attribute of plants from this family is the arrangement of four flower petals in the shape of a cross. Historically, many species from the *Brassicaceae* family, e.g., brown and oriental mustard, Brussels sprouts, broccoli, cabbage, cauliflower, kale, kohlrabi, napa, oilseed rape, rutabaga, turnip, etc. have been cultivated for their edible parts: buds, flowers, leaves, roots, stems, and seeds. Oilseed rape is currently one of this family's most widely cultivated members [1–3].

Due to the absence of populations of its wild form, the origin of oilseed rape is not fully elucidated. However, the available knowledge suggests that this herbaceous plant originated from the eastern Mediterranean and west Asian region. It is supposed to be derived about seven and a half years ago from spontaneous hybridisation between turnip rape (*Brassica rapa* L.) and cabbage (*Brassica oleracea* L.). The studies suggest that currently, several B. napus subgenomes are present: the subgenome evolved from the ancestor of European turnip, and the subgenome evolved from the common ancestor of broccoli, cauliflower, Chinese kale and kohlrabi [1, 2, 4].

Historical records indicate that the cultivation of *Brassica* genus by humanity started many years ago. Plants from this genus are known to be widely cultivated by humans more than 10 thousand years ago. Oilseed rape was cultivated in India for more than 6 thousand years and spread to China and Japan 2 thousand years ago. Later, starting from the 13th century, due to the ability to grow in relatively low temperatures and successfully reproduce with little heat, oilseed rape was cultivated in Europe. The seeds of early oilseed rape varieties were avoided to use as a food oil source, as they contained high levels of erucic acid, which has a bitter taste and can cause heart diseases. However, these negative aspects were ignored by the poor during times of poverty and crisis [1, 3, 5].

In the following centuries, oilseed rape had a limited industrial use. Apart from being used for edible purposes, due to its oil property of emitting white smokeless flame when burning, since the 16th century, it was also widely used for lighting. The list of oilseed rape application possibilities expanded with the development of steam power. During this period, the unique property of oilseed rape oil to stick to water and steam-washed metal surfaces better than other lubricants was discovered. The great need for oilseed rape oil as a lubricant for rapidly increasing forces during World War II also affected the expansion of global B. napus seeded areas. For example, before World War II, oilseed rape was grown only in small trials for research purposes in Canada. The results of these trials revealed the ability of oilseed rape to grow both in eastern and western parts of this country and stimulated the expansion of this plant [1, 3].

Another surge in the worldwide interest in oilseed rape in the 20th century appeared when in the 1970s, the 0 and 00 type varieties with low erucic acid and glucosinolates were developed. Varieties grown until then did not meet the ever-increasing needs of edible oil and protein feed, as their seeds had up to 52% erucic acid and 8% glucosinolates. The first 00-type varieties were registered in Western Europe in 1986. Their seeds contained no more than 2% of erucic acid, no more than 20 μmol/g of glucosinolates of air-dried seeds, and no more than 40% of crude fat [2, 3].

Later, especially in the last decades, the cultivated areas expanded even more with the development of breeding, which resulted in the improvement of desirable traits (greater seed yield, earlier maturity, disease, and pod shatter tolerance). The new agronomical advantages allowed oilseed rape to be increasingly grown in new countries and under different conditions [2, 5].

2. Biology

The stem of oilseed rape is 100–180 cm in height. It is branched and covered with a waxy coating. The number of branches depends on the crop density. In the dense crops, 6–7 lateral branches are formed, and in the rarer ones, there are up to 20 branches. Oilseed rape leaves are green with a bluish tint, and covered with a waxy layer. The lower leaves, with stalks, lobed and curly, and the upper ones are lanceolate, without petioles. The rosette leaves turn yellow and fall before the formation of inflorescences [1, 6–8].

The colour of the oilseed rape flower is light yellow. It blooms for an average of 3 days. Flowers are arranged on racemes. Lateral racemes are located next to the apical raceme. Oilseed rape is a self-pollinating plant, so bees are not necessary for pollination. However, it has been found that oilseed rape that is visited by bees produces a higher seed yield, sets seeds faster, and matures them more consistently. The fruit is a 4–6 mm wide and 3–10 cm long self-opening pod with round seeds of various colour: brownish, brown, black, grey-black and yellowish. The type of oilseed rape root system is a taproot. Its main root penetrates the soil up to three meters deep. Lateral roots branch off in the upper part of the main root [3, 6, 9].

Several types of this plant were developed after its introduction to Europe. According to the nature of vegetation, oilseed rape includes spring (annual) and winter (biennial) subspecies. The botanical characteristics of spring and winter oilseed rape are similar. However, both forms have some distinctive features. The growth stages of spring and winter oilseed rape correspond, but they differ in duration [1, 3, 10].

The overall life cycle of oilseed rape includes a list of different growth stages: seed germination, seedling formation, leaf formation, stem growth, budding, flowering, pod development, seed maturation and stem drying (**Figure 1**) [8, 11].

Spring oilseed rape is sown in the spring, and stem development begins immediately after germination. The rosette is formed at higher temperatures under long day conditions. This stage of oilseed rape development lasts 30–40 days. The stem growth takes 8–10 days. The mass of roots of the spring-type oilseed rape is lower than that of the winter type. Larger lateral root branches of spring oilseed rape are found at 25–45 cm depth. Spring-type plants form 20–50 flowers in the apical raceme. Blossom spreads gradually from top to bottom in the inflorescence [12–14].

Winter oilseed rape is the original form of Brassica napus. It requires vernalisation which promotes flowering. One of the distinctive features of winter oilseed rape is the cessation of vegetation in winter and the renewal of vegetation in spring. The vegetation period of winter rape is 130–180 days. The total duration of oilseed rape growth is 270–320 days. It is sown in autumn and forms a rosette of 5–10 leaves on a short stem that remains in the soil surface during winter. The terminal bud of the rosette is raised above the soil surface by 2–3 cm [7, 11].

The intensive plant vegetation renews in the following spring. The growth of the long vertical stem and formation of 2–8 new leaves of the rosette begins when the average temperature reaches 2–9°C heat. In the stage of stem extension, the height of the plant increases rapidly, and the branching of the plant begins. Inflorescences

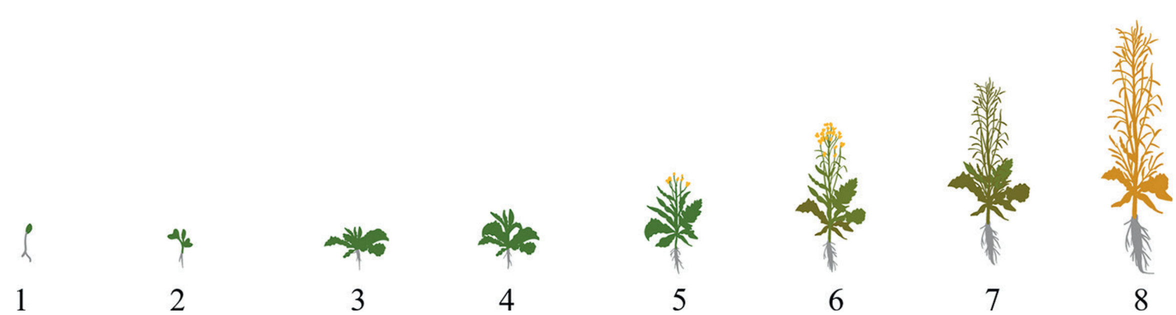

Figure 1.
Growth stages of oilseed rape life cycle: 1 - germination and emergence; 2 - leaf development; 3 - side-shoot formation; 4 - stem elongation/extension; 5 - inflorescence/flower-bud emergence; 6 – Flowering; 7 - pod/seed development and ripening; 8 – Senescence [8].

begin to form 15 days after the beginning of vegetation. The top of the stem is covered with leaves, and green inflorescences of tightly packed buds are situated between them. Winter-type plants form from 20 to 90 flowers in the apical raceme. The flowers of winter oilseed rape begin to blossom in the raceme from the bottom towards the top in the late spring. This period lasts 25–30 days. It is followed by the development of lateral branches. The total number of pods formed in winter and spring oilseed rape differs. It is higher in winter-type oilseed rape than in the spring type. The quantity of pods per plant in winter oilseed rape is from 200 to 500; in spring oilseed rape, it is from 80 to 200 pods. The average number of seeds per pod is 18-35. The average weight of 1000 seeds of winter rape is about 4–6 g [3, 6, 8, 14].

3. Prevalence

Different parts of our planet have different types of climates. Climate conditions in a particular area can determine the productivity of crops or even the ability to survive. Similarly to other crops, the prevalence of oilseed rape mainly depends on climatic conditions. It is widely cultivated in many places in the world. However, the length of the growing season is slightly variable in different climate zones. It is one of the few suitable oilseeds in the temperate zone. It grows well in relatively low temperatures, with less heat required for successful reproduction than other oilseed crops.

Moreover, the global geographical distribution of both winter and spring oilseed rape botanical forms also depends on the climatic conditions (**Figure 2**). Due to the fact that winter oilseed rape form requires the vernalisation to start the flowering process, its cultivation mostly dominates in Europe (EU countries, UK and Ukraine) and Asia. Spring oilseed rape varieties do not require vernalisation and are widely cultivated in the northern part of America, Europe, and Australia [3, 10, 15].

The global oilseed rape market consists of separate geographical segments: North America (United States, Canada, Mexico), Europe (Germany, France, Italy, Russia, United Kingdom, Spain), Asia-Pacific (China, India, Japan, Australia), Middle-East and Africa (United Arab Emirates, South Africa). Many of the world's oilseed rape market belongs to North America, the EU, and China. The major oilseed rape producers in North America are Canada, the USA, and Mexico. Oilseed rape grown in France, Germany and the United Kingdom comprises a more significant part (more than 80%) of European oilseed rape production [10, 16].

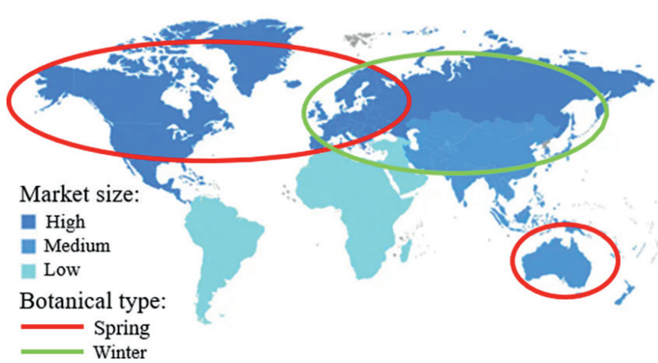

Figure 2.
Global oilseed rape market and prevalence of its spring and winter forms [10].

The studies show that oilseed rape production areas have been steadily growing with the increasing global demand for food, feed, fuel, and industrial applications. The need for oilseed rape production encourages farmers to expand their planted areas of oilseed rape. The global production of vegetable oils is expected to increase by 79–100% by 2050 [16–18].

4. The use of oilseed rape

Oilseed rape is an economically significant agricultural plant species. It is widely cultivated in many countries and is the world's second most crucial oilseed plant, which contains more than 40% of oil in its seeds. Thus, it is considered a very abundant source of oil. Oilseed rape seeds are the most widely used part of this plant. However, other parts of the oilseed rape plant are also useful [5, 15].

Oilseed rape seed oil and protein contents vary in different cultivars. The content of oilseed rape oil depends not only on the plant's genetic characteristics, but also on oil extraction conditions, e.g., solvent type, temperature, pressure, and time of processing. Many extraction methods have been tested, e.g., solvents, enzymes, gas, heat, or ultrasound. Some of these methods offer more advantages. These are safety for human consumption, less time-consuming, better oxidative stability and shelf-life, preservation or improvement of beneficial oil compounds. However, at the industrial level, the most commonly used type of extraction is the extraction by using hexane as a solvent. At the beginning of the process, seeds are heated for softening. Then they are flaked to break cell walls and cooked to promote cell disruption to release the oil. Later, residual oil is extracted using the solvent, and afterwards, the solvent is removed, and the oil is refined and processed. The negative feature of the extraction with hexane is a partial loss of beneficial antioxidants, phytosterols, and phenolic compounds [5, 19].

The types of fatty acids in the oil determine whether oil is used for edible or industrial purposes. Certain fatty acids, such as linoleic acid, are helpful for human health. They cannot be synthesised by the human body, thus must be obtained from the diet. And on the other hand, large concentrations of eicosenoic and erucic acids are harmful to human health [3, 7].

The oil obtained from the 00 cultivars is claimed to be safe both for infants and adults and is currently one of the most widely used vegetable food oils. It is valued for high nutritional value: high content of unsaturated fatty acids (which makes it more biologically valuable than animal fats), high oleic acid content, a favourable ratio of linoleic and linolenic acids, and abundance in vitamin E. It is also famous for its affordability, high cooking temperature, mild flavour and versatility as a cooking oil. It can be used at room temperature, e.g., as a salad dressing or for baking. In addition, it has been established that glucosinolate hydrolysis products can activate the human body 's protective mechanism. Glucosinolates are responsible for the pungent odour and taste, which ranges from the hot flavour in mustard seed and horseradish to the more subtle flavours of rutabaga and cauliflower. Therefore, the consumption of plants of the *Brassicaceae* family in the human diet may be associated with a lower risk of cancer [1, 3, 7, 20].

The high demand for oilseed rape oil is also related to the use of this oil for the production of biofuels. European Parliament promoted the use of biofuels by issuing Transport Biofuels Directive in 2003. It induced a dramatical increase in oilseed rape cultivation in Europe. The biodiesel produced from this renewable energy source is about 40% less polluting than diesel [1, 10, 15, 21].

Another valuable property of oilseed rape biodiesel is maintaining a fluid state even at low temperatures, and overdue of crystal formation, which makes it suitable for cold climates. Also, oilseed rape oil emits up to 90% less greenhouse gas (GHG) than fossil diesel. Thus, its use can reduce the emission of GHG from the transport sector and diminish the degradation of environmental wellness. What is more, oilseed rape biodiesel is biodegradable. It decomposes for about 30 days and accelerates the decomposition of diesel fuel when mixed. It is less toxic in water, thus reducing the impact of spills in sensitive areas. Biodiesel is often blended with fossil-fuel diesel in ratios of up to 20 per cent of biodiesel. Despite the numerous benefits, this biofuel also has disadvantages. It is vulnerable to oxidation during storage, and it can degrade some materials made of elastomer and rubber in fuel distributions. Also, due to the costs of growing, crushing, and refining oilseed rape oil, its price is higher than standard diesel fuel. Thus, biodiesel fuels are commonly made from used oil. Oilseed rape is used not only for producing edible oil, technical oil and biofuel, but also for other market needs [1, 3, 22].

A high erucic acid oilseed rape (HEAR) cultivar with erucic acid contents up to 66%, increased oil yield and increased tolerance to diseases and stress were used to make useful products, e.g. slip agent for the plastic film, emollient, food emulsifier, photographic material, ink, paper, textile, foam, plastics, etc. Moreover, oilseed rape can also be used in cosmetics and soap production. The soap is made in a cold process to save the beneficial compounds, light colour and dense. Coconut or other oils can be added to add to the aroma. Oilseed rape oil is also used as a biolubricant for biomedical applications (e.g., as a lubricant for artificial joints), as a personal lubricant or to replace 70% or more petroleum in chain saw oil. Besides, erucic, oleic and linoleic acids are helpful for maintenance of healthy hair and scalp conditions. Furthermore, a low-toxic and rapidly decomposing human and environment-safe pesticide was developed from oilseed rape oil. This insecticide is irritating and is used to fight aphids, loopers, worms, caterpillars, and mites [3, 5].

Oilseed rape meal, the residue after extraction, is widely used as a soil fertiliser, protein-rich and a functional additive for animals (cattle, pigs and birds) and human feed, as a substrate for fungi to produce enzymes (e.g., xylanase, xylosidase, cellulase, and acetyl–xylan esterase). Its incorporation in wheat, soybean, or corn-based diets affected feed efficiency, protein digestibility, energy value, and microbial community. It is also used in manufacturing capsules for bioactive drug delivery, cosmetics, and bioplastic packaging [5, 23].

Oilseed rape leaves, stems, roots, flowers, and seeds can be used for human food. Leaves and stems are a rich source of minerals, proteins, vitamins, and phenolic compounds. Their regular consumption is beneficial for human health by preventing chronic diseases. They can be used as edible vegetables or as a pot herb for seasoning. Oilseed rape flowers can be used as tea. Pollens can be consumed to strengthen the immune system and fight cancer. Seeds can be used as spices. Oilseed rape roots are also helpful due to their various diuretic, antigout, antiinflammatory, and antiscurvy characteristics [5, 9].

In animal husbandry, oilseed rape is used for green fodder and silage. Also, it is valued by beekeepers as a rich source of nectar and pollen for honeybees. It has been considered the main plant from which bees collect nectar. It has been shown that 1 hectare of oilseed rape yields 60–90 kg of honey. The period of oilseed rape flowering is about 1 month. Thus, oilseed rape provides good shelter and supplies nutrition for a long time. Oilseed rape honey has a mild medicinal, taste and aromatic properties. Its flavour is peppery, and the texture is soft-solid. It is whitish or milky yellow. It is often used as a sweetener, in confectionery and for processing [5, 24].

Oilseed rape is a deep-rooted plant that can absorb useful substances from deeper soil layers with its long taproot. Glucosinolates, formed from glucose and amino acid and containing sulphur, perform an essential defensive function in plants of the *Brassicaceae* family, protecting crops from pests and diseases. It releases volatile mustard oils and dissolves and assimilates nutrients that are difficult for other plants to obtain. After oilseed rape harvesting, many organic residues remain in the soil. It increases the amount of humus, improves the soil fertility, structure, and porosity, improves beneficial soil bacteria and alleviates or suppresses infections, nematodes and the growth of some weeds. Additionally, crop growth and development may be enhanced with the oilseed rape hormone brassinolide [3, 11, 12].

Due to these properties, oilseed rape is also grown as a green fertiliser and is an essential crop in many arable rotations. Often, it is grown as a break crop in three to four-year rotations with cereals (e.g., wheat and barley) and break crops (e.g., peas and beans). This provides many benefits for pest and disease control by reducing the possibility of pests and diseases being carried over from one crop to another. For example, it is helpful for wheat yield due to fungus-removing properties, when wheat is sown after sowing oilseed rape. Some cultivars of oilseed rape are also used as an annual forage [11].

Oilseed rape has a long flowering period. Its flowers are widely used for ornamental purposes, e.g., to decorate indoors and outdoors and as a field to visit for leisure. Hybridisation techniques enabled colourful (white, milky white, golden yellow, orange, purple, pink, and red) flowers [5, 9].

Oilseed rape plants can also be used for phytoremediation. Their roots can absorb and accumulate heavy metals from the soil rich in heavy metal contamination, e.g., cadmium (Cd). The absorbed heavy metal stems above and is removed when the plant is fully grown. Also, it has up to a three times higher rate of radionuclides uptake compared to other grains. Thus, it was researched as a tool to decontaminate the soil after the Chernobyl catastrophe [3, 5].

Finally, agricultural waste of oilseed rape is also useful. After its seeds are harvested, straws still contain a sufficient content of proteins, which is higher than wheat and legume. Thus, oilseed rape straw is used for animal feed. The only disadvantage of using straw as animal feed is a large amount of fibre, which lowers digestibility. However, it can be removed using ammonia treatments. Moreover, pods, stalks and cake are pressed and used for biofuel, as a substrate in vermicomposting and for the production of biochars [3, 5, 11].

5. Growth conditions and agronomic management

Oilseed rape seeds start to germinate at 2–3°C. However, the most favourable germination temperature is 12–16°C. Their seeds germinate at this temperature and normal soil moisture in 5–7 days. However, their germination may take up to 20–30 days in a dry period. The temperature over the growing season has a significant relationship with yield. The optimum temperature for oilseed rape growth is 20–21°C. Temperature higher than 30°C is harmful for pollination and shortens the pod and seed development phase, thus reducing yield and quality. Moreover, high temperature during winter hastens plant growth, shortens the growing season, and reduces yield potential [18, 25].

Winter oilseed rape withstands up to −3°C cold in autumn. And with a rosette containing 5–7 leaves, and a snow cover thicker than 6 cm, it withstands up to

−25°C frosts in winter. However, under snowless and frost conditions, or when the seedlings overwinter with only 3–4 leaves, the plants die at −12°C cold. Low temperatures mainly damage the root collars and terminal buds of winter oilseed rape. Also, winter oilseed rape is sensitive to spring temperature fluctuations, as the plant consumes many nutrients during the winter and is, therefore, most vulnerable at that time [25–27].

High yields of oilseed rape are obtained when the plants are optimally developed before flowering. For optimal growth, oilseed rape should be planted in a well-drained and finely tilted area with a pH ranging from 5.5 to 8.5 and with moderate soil salinity for optimal growth where *Brassica* crops have not been planted for at least 3 years. What is more, the level of the primary nutrients (nitrogen, phosphorus, potassium, and sulphur) should also be maintained. The requirement of nitrogen ranges from 45 to 70 kg per acre. The recommended rates of phosphorus range from 0 to 30 kg per acre, depending on the current levels in the soil. And the recommended rates of potassium range from 0 to 65 kg per acre according to present soil fertility levels.

Several types of tillage systems are currently used in oilseed rape cultivation. The conventional tillage system is the most commonly used type of tillage system. Parallelly, few alternative tillage systems are used, e.g., the reduced tillage. Nevertheless, it has no significant effect on the oilseed rape yield it is confirmed as the valuable alternative to conventional tillage due to lower fuel and labour consumption and sustainability. To ensure successful reduced tillage practice special conditions must be met. These are the diverse crop rotation, the use of combine with straw chopper and chaff spreader qualities [28–30].

Weed control is the other challenging task for oilseed rape growers. One of the important parts of weed control is the establishment of weed-free fields. Thus, grass and broad-leaved weeds should be targeted, and the oilseed rape seeds should be sown as soon as possible: for winter type – immediately after the harvest and for the spring type – as soon as soil moisture is sufficient for entry of machinery. Nevertheless, the use of herbicides is very effective weed control method, due to their presence in drinking water, health damaging properties and increasing herbicide resistance in certain weed species, the restrictions on herbicide use are getting tougher.

The type of tillage method also has an impact on weed potential. A higher risk of grass weeds and germination of cereal crop grain shed from previous harvest may be present when the soil is prepared by reduced tillage method, because seeds of some weed species after ploughed down in previous rotation may be ploughed back up to the soil surface. Thus, bearing in mind that some weed species have a durable seed-bank, and can reappear in ploughed soil, then 1 year at depth ploughing may be a good strategy for their control. The other tool for oilseed rape weed control is the use of various types of herbicides. E.g., non-selective herbicides are often used for weeding control in inter-row gaps, and the application of the residual herbicides is beneficial due to the season-long weed control. However, despite the success of herbicide applications there are few disadvantages of their use: herbicides are harmful for health and are being found in drinking water, herbicide effectiveness of certain herbicides has declined due to the increasing herbicide resistance in some weeds. The occurrence of these shortcomings resulted in introduction of legislation changes [31–33].

The maintenance of the optimal density of the crop is also essential. For oil production, oilseed rape is seeded directly into soil, aiming to achieve a density of 25–40 plants/m^2. Too dense crop leads to the formation of weak plants. Biometric analysis of the crops showed that weaker oilseed rape plants remain in the shooting stage. Thus, most of these plants are overshadowed by stronger and faster-growing oilseed rape plants and eventually die [3, 34].

The other mean factor for oilseed rape yield is the distribution of rainfall. The rainfall is undesirable after maturity. However, a long rainy season with sufficient rain and lower temperature during earlier developmental stages is very favourable [3, 10]. The sufficient humidity level in the soil is dramatically important for high oilseed rape yielding, especially during the stages of flowering, yield formation and ripening. Therefore, under conditions of water scarcity, irrigation needs to be applied to avoid the loss of yield. Studies have also showed that irrigation at the beginning of flowering improves nitrogen assimilation and oil content [35, 36].

A complex of actions and measures is taken to increase the yield of plants. One such action is the use of growth regulators. Aiming to improve oilseed rape yield (to stimulate growth and flowering, inhibit plant elongation and the opening of productive elements, protect against diseases and pests, enhance the quality of harvest and quantitative indicators, product nutrition, restore damaged plants and increase resistance to adverse environmental conditions, such as drought, flooding, cold etc.) a list of growth regulators (growth hormones, osmoregulators, retardants, fungicides, etc.) has been tested and used till now. Scientific studies show that the effect of exogenous compounds can cause physiological changes in the plant cell and change the defence response to biotic and abiotic environmental factors [3, 25, 37, 38].

6. Diseases and pest management

Oilseed rape plants can suffer from a comprehensive list of enemies, starting with the viruses and finishing with mammalians. Their main fungal diseases are canker, light leaf spot, *alternaria*, and *sclerotinia* stem rot. The canker symptoms are leaf spotting, premature ripening and stem weakening in the autumn-winter period. The treatment of fungicides conazole or triazole is applied in late autumn and spring to fight this disease. The light leaf spot disease is caused by the fungus *Pyrenopeziza brassicae*. This disease can be recognised by speckles of white spore pustules on leaves, stems and pods, which become visible only after a period of dry weather. *Alternaria* fungi species causes leaf spots. It can penetrate the pods and infect the seed. *Sclerotinia* is dangerous when lower main stems are infected. Infection can stop the food and water supply to the canopy and cause the death of the plant. Broad-spectrum fungicides are used to control *alternaria* and *sclerotinia* development [1, 39, 40].

Also, oilseed rape can be attacked by a wide variety of insects. The most common insect pests that attack oilseed rape are the cabbage stem flea beetle (CSFB), *brassica* pod midge, rape stem weevil, cabbage seed weevil, cabbage stem weevil, and pollen beetle. CSFB is currently the main oilseed rape pest enemy. Adults of CSFB graze on young oilseed rape plants and can cause plant death. CSFB larvae also mine within the petioles and stems of plants. Lower chances of CSFB spread are considered in areas where oilseed rape has not been grown recently or nearby [3, 40].

Despite continuously developing CSFB management relying on a variable and complex set of alternative solutions, it has recently become more challenging to control. First, due to a reduction in effective chemical control options: resistance to pyrethroid sprays and the withdrawal of neonicotinoid seed treatments. Foliar application of pyrethroid insecticides was the most approachable chemical control of CSFB in oilseed rape. However, the resistance to pyrethroid insecticides is now widespread, and lessens the control's potential. Thus, when CSFB resistance to pyrethroid insecticides has developed, measures must be taken. Subsequent pyrethroid applications are recommended to avoid. This is to stop the selection for resistance and harming natural enemies [3, 41].

Otherwise, it is essential to follow the spray thresholds and cure a full field. The decrease in effective chemical options in oilseed rape has spurred the rise of CSFB. Reducing oilseed rape areas in certain regions is often associated with a higher prevalence of CSFB. Thus, crop protection requires innovation in this pest management. There is a need to find novel approaches to control CSFB, e.g., breeding varieties with greater resilience to CSFB, using biopesticides or others. Presently there are no varieties available to control any pest of oilseed rape. Little attention is paid to biopesticides to control CSFB have received. Biopesticides serve as a pest control option. They cause a minimal environmental impact, are specific to the target pest and can be a tool for resistance management [10, 40].

Oilseed rape is particularly vulnerable to pest damage at the early stages of growth. And it is far more tolerant to attack after the cotyledons have unfolded. The need for treatment can be determined by the number of shot-holing symptoms, leaf area eaten by beetles (**Figure 3**) or larvae and the plant's growth rate. Along with the adult beetle harm, the autumn, winter and spring CSFB larval assessment in leaf petioles and stem is present. It needs to be highlighted that the larval damage may be more economically harmful. Autumn larvae are more damaging, as their consumption of plant material last longer, and winter and spring larval invasion is likely to be less significant. If the risk is high –treatment at the first sign of attack is recommended to

Figure 3.
CSFB holing symptoms in oilseed rape.

be considered at the initial stages of growth. For the latter growth stages, such fields should be set up with traps, and the number of pests should be monitored not to exceed [1, 4, 6].

Effective chemistry is considered the best CSFB management option, however, no individual chemical or non-chemical approach is absolutely warranted. Thus, a combination of techniques is recommended for CSFB population suppression. Several alternative methods need to be mentioned. It is important not to damage natural enemy populations, e.g., ground beetles and parasitic wasps, by pesticide applications (especially broad-spectrum pyrethroids) and intensive cultivation. Great benefits were obtained in trials with trap crops. This approach uses trap crops to attract CSFB and simultaneously divert it away from oilseed rape. Afterwards, CSFB eggs or larvae die when the trap crop is destroyed. The disadvantages of this approach are that the use of relatively large areas of trap crops (at least 2 ha) is recommended and that the benefits can be variable. However, the trial approaches showed up to 88% reduced adult CSFB infestation and 76% reduced oilseed rape damage. It is recommended for a trap crop to be at an early growth stage at the end of August. This could make it more attractive to CSFB [40–42].

As an alternative solution, the selection of cultivars is recommended. The susceptibility or attractiveness of different varieties to CSFB has not been evidenced. Nevertheless, it is recommended to choose hardy varieties in the context of CSFB control. Such varieties can reach the four-leaf stage faster. This property makes the plant more tolerant to CSFB adult and larvae feeding damage [3, 4].

The maintenance of optimal soil humidity during crop germination is essential. Aiming to provide sufficient moisture levels, sowing dates should be adjusted regarding the soil humidity level and weather conditions and forecast. In addition to maintaining soil humidity and enriching the soil with organic matter, the cereal stubble and straw also have several benefits of their presence in the field for CSFB management. It is suggested that stubble and straw make it difficult for CSFB to locate the germinating oilseed rape and are useful as a support for spider web [1, 5].

The date of sowing is also shown to play a vital role in the CSFB management. Avoiding the alignment between beetle migration peak and the most susceptible crop growth stages is recommended. . The sowing period of the highest risk from adult CSFB lasts from the end of August to early September. The early sowing ensures successful oilseed rape germination and establishment before the CSFB migration. The late sowing reduces an adult CSFB beetle feeding damage by moving the germination after the migration peak and reducing the larval invasion by slowed egg laying and development under cooler conditions. Studies have shown that a 10-fold reduction in larval invasion is obtained by a three-week postponement of sowing.

The optimisation of seedling density can also be used to reduce the risk of CSFB damage. To achieve final optimal plant density under the threat of CSFB invasion, the seed rate needs to be increased. And on the other hand, by decreasing the seed rate, plants may grow larger and more tolerant of larval feeding in the spring [6, 34].

Companion crop species are known to prevent or lessen crop damage by attracting the pest, improving soil, masking the crop from pests, or offering shelter for natural enemies. For example, mustards act as sacrificial plants that are eaten first. The research on CSFB management has detected significantly lower damage in two-leaf and five-leaf stage oilseed rape cultivated with a list of companion crop species. Buckwheat, legumes and *Brassicaceae* family members are known to play a preventing role in CSFB management. The companion crop should be sown about a week before oilseed rape and can be removed by frost or by the herbicide. It should also not outcompete oilseed rape [3, 7, 41].

As CSFB larvae generally settle in leaf petioles, trials have shown that managed defoliation reduces larval invasion by up to 55%. It has also been found that sheep grazing and topping/flailing are effective in reducing larval populations. The most beneficial is late defoliation before stem extension (November and December). Later defoliation could be dangerous due to a lack of time for plants to recover. It is also suggested that CSFB damage could also be reduced by the addition of organic amendments during the establishment period. The use of organic amendments may be helpful to for CSFB invasion management by improving plant growth, masking the crop, and repelling the pest. Moreover, crop tolerance to larval damage can also be enhanced by proper nutrition and plant growth regulation. It should be noted that the management tools proposed to control the CSFB spread are also useful in eliminating many other issues in oilseed rape cultivation [12, 40].

7. Oilseed rape breeding

Breeding is an excellent tool for improving many crops' preferred characteristics. The most common desirable traits usually are higher yield, resistance to stress and diseases, and improvement of specific characteristics of the plant. Breeding is a time and resource-consuming technique. The process of cultivar development, starting with initial crosses and finishing with commercial registration, takes about 10 years. Many advances have been achieved in oilseed rape improvement due to the collaborative effort of plant breeders, pathologists, physiologists, agronomists, and other specialists. These efforts reduced production risks for farmers who grow these cultivars and resulted in greater seed yield, modified content of seeds, earlier maturity, disease, and pod shatter tolerance [1, 4].

Crosses are made between perspective genetic material and selected for desirable seed yield, the presence and content of seed components, e.g., specific amino and fatty acids, oil, protein etc. During the oilseed rape breeding history, the contents of unwanted compounds found in the oil, such as erucic acid and glucosinolates, were significantly decreased to ensure safe use for edible purposes. Moreover, the oil content, seed yield, and disease resistance have also significantly improved. Knowledge about the relationships between closely related species is essential for plant breeders. It is an excellent source of genetic material for developing new cultivars. There is a significant number of created winter and spring oilseed rape cultivars. They are sorted according to their characteristics [1, 12, 23].

HO and LL (high oleic and low linolenic fatty acid content) cultivars, due to the modified contents of oleic and linolenic fatty acids, are healthier for human health. The stable oil of HO and LL varieties benefits the food processing industry [7, 15, 43].

LEAR (low erucic acid oilseed rape) development started in 1960, when oilseed rape plants with low eicosenoic and erucic acid contents were isolated by Canadian breeders after the high eicosenoic and erucic fatty acid contents were questioned. Soon, in 1967, seeds of cultivar 'Bronowski' were found to have a low content of glucosinolates. This genetic source of low concentration of glucosinolates was then used to develop cultivars with low levels of erucic acid and glucosinolates ("double low" cultivars). Multiple improvements of oilseed rape cultivars throughout the breeding process dramatically reduced erucic acid levels. These cultivars are used for edible oil production. The current standard requirement for these cultivars is less than 2% of erucic acid in the fatty acid profile and less than 30 micromoles of any one or a mixture of the glucosinolates (3-butenyl glucosinolate, 4-pentenyl glucosinolate, 2-hydroxy-3 butenyl glucosinolate, and 2-hydroxy- 4-pentenyl glucosinolate) per gram of air dry and oil-free solid. The reduction of the content of glucosinolates expanded the use of oilseed rape meals in animal husbandry [1, 3, 7, 16].

HEAR cultivars were developed for non-edible purposes. They are commonly grown for industrial use. HEAR cultivars are used to produce lubricants, plastics, lacquers, and detergents. Reducing the levels of glucosinolates enabled the usage of HEAR cultivars as livestock feed [5, 23].

The characteristics of oilseed rape can also be modified by hybrid seed production. An oilseed rape hybrid results from crossbreeding two oilseed rape lines. And the more distant the parents, the greater the hybrid power. It was observed that hand crosses between two distant lines of oilseed rape result in up to 45 per cent higher seed yield than in parent lines. It was shown that oilseed rape hybrids have higher stability, disease resistance, and yield. However, the by-hand method is time and source-consuming and thus hardly possible at a large scale. Since oilseed rape cultivars are mostly self-pollinated thus, self-pollination of parental lines must be controlled during the hybrid creation process. Therefore, several approaches have been developed to produce oilseed rape hybrids [7, 12].

One of the developed hybridisation systems is the cytoplasmic male sterility (CMS) system. The first commercial CMS oilseed rape hybrid was registered in 1989. Its use enables oilseed rape breeders to produce female plants that either do not produce pollen, do not shed pollen or make pollen that cannot cause self-fertilisation. Its use allows canola breeders to grow female plants that either fail to produce pollen, do not shed pollen, or which pollen cannot self-fertilise. This system was invented after discovering that some *Brassica* species have male-sterile cytoplasm. Fertility is determined by an interaction of the nucleus and cytoplasm. A mutation in certain cytoplasmic bodies disables the development of functional pollens or anthers [3–5].

The hybrid system usually consists of three lines: a male sterile, a maintainer and a restorer line. The male sterile female plant flowers have a sterile cytoplasm due to the gene isolated from the soil bacterium and inserted into this line. The inserted gene controls the production of the particular enzyme in the specific cell layer. It disables the development of pollen. Thus, these plants cannot self-pollinate. These flowers are crossed with the genetically identical maintainer line, which produces pollen. This line contains another gene obtained from the same soil bacterium. This gene has an inhibitor enzyme that counteracts the sterility enzyme in the male sterile line to restore fertility. The obtained seeds maintain CMS characteristics. The restorer line is genetically different from the male sterile line. It contains genes that compensate for the cytoplasm gap and restores fertility in the hybrid. The 100 per cent hybrids are obtained by inserting the target gene into both parental lines. A hybrid tolerant to the herbicide glufosinate ammonium was developed using this kind of breeding technique [5, 44].

The other breeding method is the production of "synthetic" cultivars. It exploits the heterosis present in the Brassica family. Synthetic oilseed rape cultivars are developed by mixing seeds from two or more parental lines from two lines and by growing out the mixed seed to produce certified synthetic seed. The synthetic seed, including hybrid and parental plants, is more stable under various environmental conditions than conventional cultivars. The degree of outcrossing depends on the insect pollination degree; thus, it is unpredictable. A mixture of the parental lines and all possible hybrids between them will be obtained in the next generation. A list of herbicide-tolerant cultivars has been developed using mutagenesis and gene transfer. These cultivars are tolerant to specific herbicides or their groups. The first triazine-tolerant oilseed rape was registered in 1984 in Canada. It was developed to enable the cultivation of oilseed rape in areas infested with weeds of the *Brassicaceae* family, e.g., wild mustard, stinkweed, and ball mustard. Later, cultivars tolerant to imidazolinone, glyphosate (Roundup), glufosinate ammonium and bromoxynil were developed. It was demonstrated that isogenic lines have different energy use efficiencies under certain growing conditions due to epigenetic differences [1, 5, 45].

8. Future prospects

Nevertheless, much effort has been made in oilseed rape cultivation, breeding, and production improvement. Still, there are issues that need to be solved. The improvements of oilseed rape cultivars should be oriented to enhance the tolerance to the environment, especially for xeric conditions, disease, and herbicides, to eliminate green seed, increase yield, develop early cultivars for short season environments and improve nutrient use efficiency.

Also, an effort should be made to improve cultivars for lodging and pod shatter tolerance. The studies should also be oriented to explore new possibilities to use oilseed rape in producing new biodegradable products, develop sustainable solutions for oilseed rape cultivation, explore beneficial oil extraction methods, and improve pest control management. And finally, the benefits and the harm of oilseed rape use for human health should be better examined.

9. Conclusions

Oilseed rape is a member of the Brassicaceae family. This crop is commonly known as the oilseed rape, rapeseed, canola or colza. It has been grown for thousands of years for its oil content, and currently, it is one of the most commonly used sources of vegetable oil. Oilseed rape oil is used for edible and nonedible (industrial) purposes with various end uses, including fuels and bioproducts. It is also used as a source of protein for food and industrial applications, as a remedy, as an ornamental plant, as a fodder crop, as the source of nectar and pollen, the source for the production of cosmetics and biodegradable products and many other purposes. It is helpful to complete human and animal nutrition and prevent or fight certain diseases. All parts of oilseed rape are useful. Even the waste is used for various needs, e.g. to feed animals, recycle or fertilise the soil [1–3].

Oilseed rape oil is one of the oldest known vegetable oils, however historically, it was used in limited quantities due to high levels of erucic acid, which is damaging to cardiac muscle, and glucosinolates due to antinutritional values and adverse physiological effects when present at above the tolerance level are damaging the thyroid, kidney and liver. During the oilseed rape breeding process, erucic acid and glucosinolate in the seeds have dramatically reduced. In contrast, oil content, seed yield, and disease resistance have been significantly improved. Improved end-use quality has increased the market for oilseed rape seed and its products [19].

Oilseed rape is a very productive oil source. It produces more oil per unit of land area than other oil sources. Its productivity depends on a list of factors. These are the genetic potential, the characteristics of the environment (soil, humidity (water), climatic and biotic conditions) and management strategies (crop sequence, rotation, and tilth options). Also, nevertheless, oilseed rape is a self-pollinating plant;

however, the pollination by bees increases the final yield. Moreover, winter oilseed rape is, on average, 45% more productive than spring oilseed rape [12, 16].

This review summarises the knowledge on oilseed rape importance, prevalence, breeding improvements and the issues of its cultivation and management.

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Conflict of interest

The authors have no conflicts of interest to declare.

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