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IMPROVING THE EFFECTIVENESS OF INTEGRATED PEST MANAGEMENT OF WINTER OILSEED RAPE IN LINE WITH THE EUROPEAN GREEN DEAL

INSTYTUT OCHRONY ROŚLIN
PAŃSTWOWY INSTYTUT BADAWCZY

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Publication was funded by Oilseed Promotion Fund

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EXPERT REPORT for the Polish Association of Oil Producers
Improving the effectiveness of integrated pest management
of winter oilseed rape in line with the European Green Deal

Publication was prepared by Institute of Plant Protection – National Research Institute
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Project coordinator: Adam Stępień

Graphic design and typesetting: printomato.pl
Print: KRM Druk sp. z o.o.

ISBN: 978-83-959757-5-2

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Warsaw 2021

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GLOSSARY

COBORU – Polish Official Variety Testing
GUS – Central Statistical Office
IP – Integrated Production
KR – The Polish National List of Agricultural Plant Varieties
PDO – Post-Registration Variety Testing System
AS – active substance
PPP – plant protection product
TuYV – turnip yellow virus
CAP – Common Agricultural Policy

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FOREWORD FROM THE AUTHORS OF THE EXPERT REPORT DRAWN UP FOR POLISH ASSOCIATION OF OIL PRODUCERS

INSTYTUT OCHRONY ROŚLIN
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In Poland, winter oilseed rape is the most important oilseed crop, and its sown area is constantly increasing and amounts to almost 1 million ha. Agroclimatic changes, simplified production technologies and large sowing area of winter oilseed rape result in an increasing economic importance of agrophages, i.e. diseases, weeds and pests. In Poland there are almost 100 agrophages, of which 15 pests, 8 pathogens and 10 weed species are the most important from the economic point of view.

Introduction of the obligation to use integrated pest management throughout the European Union as of January 1, 2014, contributed to the reduction in the use of plant protection products in winter oilseed rape from 1.97 kg/ha of active substances to only 1.74 kg/ha. Currently, herbicides are mostly used (0.92 kg/ha); they are followed by fungicides – 0.45 kg/ha and insecticides – only 0.28 kg/ha of active substances. In Poland, 2.5 kg/ha of active substances is used on average, while in the entire EU it is 3.5 kg/ha.

The EC Strategies "Farm to Fork" and "Biodiversity Strategy" recommend a 50% reduction in the use of plant protection products within 10 years. This provision is applicable only to the 10 EU countries using plant protection products in the amount exceeding the average; the countries using fewer preparations should rationally increase the chemicalisation of production, including through the use of non-chemical methods, mainly biological agents.

In the near future, the number of various modern biological agents will increase rapidly, which will make it possible to at least partially limit the negative impact of extensive withdrawal of active substances on winter oilseed rape production.

The future of oilseed rape lies in new varieties that are resistant and tolerant to pathogens, especially to clubroot, turnip yellow virus (TuYV), and stem canker. This allows for a reduction in the chemicalization of winter oilseed rape production and has a beneficial effect on the agricultural environment.

Within the framework of the CAP 2021-2027, the EU will financially support the use of biological agents and the sowing of pathogen-resistant and pathogen-tolerant varieties, as well as certified integrated crop production, including of winter oilseed rape.

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EUROPEAN *GREEN DEAL* AND THE EC *FARM TO FORK* STRATEGY IN THE CONTEXT OF PROTECTION AND PRODUCTION OF WINTER OILSEED RAPE

As a part of the European Green Deal, the European Commission on May 20, 2020 adopted two Strategies – "Farm to Fork" and "Biodiversity Strategy".

These strategies specify that the use of plant protection products should be reduced by 50% within ten years, while fertilisation will be reduced by 20%. Currently, the EU is developing secondary legislation that precisely defines the requirements for individual agricultural and horticultural producers.

The average use of plant protection products in Poland and in the whole EU is calculated as the amount of kg/ha of active substances of plant protection products; therefore, the amounts used in particular countries can be subjected to comparison.

In Poland such final calculations are performed by the Institute of Plant Protection – National Research Institute. This information is provided by GUS and Eurostat.

In the EU 3.5 kg/ha of active substances is used on average; in Poland it is only 2.5 kg/ha. The highest amount of active substances is used in the Netherlands – 8, in Italy – 6.5, in Germany – 4.5 and in France and Spain – 4 kg/ha each. Only a few countries use smaller amounts of active substances than Poland: Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Lithuania, Latvia and Slovakia. In Poland the least amount of plant protection products is used in the production of agricultural crops (approximately 0.5 kg/ha in the cultivation of oats, spring barley, spring wheat and cereal mixtures. More than 1.3 kg/ha is used to protect winter wheat. In Poland, 1.74 kg/h of active substances is used in protection of winter oilseed rape, including 0.92 kg/h of herbicides, 0.45 kg/h of fungicides, 0.28 kg/h of insecticides and 0.09 kg/h of plant growth and development regulators. Larger amounts of active substances are used to protect potatoes – 3.5 kg/ha and sugar beet – 2.6 kg/ha. Horticultural crops, apple orchards in particular, require the use of approximately 10 kg/ha of active substances, however, in other countries leading in the production of apples (e.g. USA), these amounts exceed even 13 kg/ha.

The EC Farm to Fork Strategy aims at reducing the use of plant protection products in EU by 50%. According to the data collected by Eurostat, 4 countries: France, Spain, Germany and Italy together use as much as 65% of all plant protection product used in the EU, while using only 45% of arable land. These countries should strive to enforce the most significant reduction in the use of chemicals in plant protection.

By implementing the EC Strategy, Poland may even reasonably increase the use of plant protection products in agricultural crops, while in some horticultural crops there should be a reduction in chemicalisation.

The main objective of plant protection is to secure the quantitative and qualitative safety of plant raw materials. Changing agroclimatic conditions affect the development of plants and result in the occurrence of agrophages (pests, diseases, weeds) on plantations, which reduces the yield of crops from about 10% to – in extreme cases – to the complete destruction of plants.

All current crop varieties, including winter oilseed rape, are cultivated to produce very high yields, but require protection when placed in conditions rich in agrophages, namely diseases, pests and weeds. Currently, breeding of new varieties aims at achieving high resistance or tolerance to abiotic (environmental) and biotic components, i.e. also to agrophages. Such varieties do not often require protective treatments, which is good for the environment, but they are resistant only to single agrophages, which is not a complete solution of the plant protection problem.

In modern technologies of plant production, fertilization generates the highest costs (approximately 40%), while plant protection is getting more and more expensive and constitutes from 20% to 30% of all expenditures on cultivation. The EU's restriction of active substances has a diminishing effect on competition between phytopharmaceutical companies, which can already be seen in 2021 in the form of a large increase in plant protection products prices.

In the EU, since 1 January 2014, it is mandatory for all agricultural and horticultural producers to apply the system of integrated pest management, which makes it possible to produce raw materials that meet high requirements in terms of plant health and quality safety. Such requirements generate large costs, which are partly borne by the farmer and the gardener, and, as a consequence, by each consumer.

Third countries do not have an integrated pest management system and preparations that have been banned from use in the EU long ago (for environmental reasons) may be used. All modern plant protection products have a very short effect on pests and often require repeated treatments, which generates additional costs. By using "old" active substances outside the EU, crop production costs can be significantly reduced, however, this may affect the quality of the raw materials.

The strategies developed by EC are very ambitious, as they assume a 50% reduction in the use of plant protection products and a 20% reduction in plant fertilisation. Implementing these assumptions within the course of 10 years will require additional funding from the CAP 2021-2027 budget. The strategies assume an increase in the use of biological methods, which are about 5 times more expensive than chemical plant protection products. There will also be an increase in the use of varieties that are resistant or show less susceptibility to diseases or pests. Seed of such varieties can be even three times as expensive as the seed of conventional varieties. As a result of the withdrawal of certain active substances or methods of protection (seed treatments), the workload will increase due to the increased number of treatments carried out, often as a result of the short duration of their impact. Biological methods have already been massively used in greenhouses for several years to control all pests and some pathogens. In greenhouses, the conditions (e.g. temperature, humidity, sunlight and UV rays) that are needed for the effective action of biological preparations can be continuously adjusted. Unfortunately, on open-air plantations agroclimatic conditions which significantly reduce the effectiveness of biological preparations cannot be so easily adjusted. In agricultural and horticultural cultivation, biological methods are currently used practically only in organic production.

In Poland and other countries almost 100% of cultivation methods used in greenhouses are biological methods, allowing for production of e.g. vegetables without the use of chemicals, which is always marked on commercial packaging.

In the field cultivation of corn, biological methods are applied only on approximately 5% of the cultivated area; trichogramma is used to destroy the eggs of the European corn borer. The main reason for the rare usage of biological methods in the field cultivation of agricultural and horticultural crops is the frequently unsatisfactory effectiveness in fighting agrophages, most often resulting from improper thermal and moisture conditions. In Poland, pluvio-thermal conditions in individual years during the growing season of plants range from extremely wet to extremely dry. Currently in Poland a total of over 250 plant protection products are registered, of which only approximately 50 are biological preparations. A few years ago other EU countries were in a similar situation, but as a result of the introduction of targeted subsidies for the purchase of biological products, the share of biological preparations already exceeds 20% and the percentage is still rising. In Poland, in addition to subsidies for the purchase of biological preparations, large financial resources from the CAP 2021-2027 budget should be used to train advisors and producers of agricultural and horticultural plants. The use of biological methods requires improved precision and knowledge due to the optimal conditions of action on pests.

To protect winter oilseed rape, only 4 biological plant protection products (for plant or soil spraying) and 1 seed treatment are currently used.

Winter oilseed rape cannot be cultivated without using plant protection products. Winter oilseed rape is cultivated on fields for approximately 11 months and during this period the crops are attacked by over 100 agrophages. In addition, most field cultivations of winter oilseed rape are of economic importance. The reason for the high attractiveness of new oilseed rape varieties for agrophages lies in the almost complete removal of glucosinolates (as a result of breeding). Towards the end of the 20th century, the glucosinolate content of oilseed rape was reduced 10-fold, which resulted in the deprivation of plants of their natural protective barrier against pathogens and pests. This produced oilseed rape meal that can be fed to all livestock, but the crops' natural defences against agrophages were impaired.

In Poland, in the organic system mainly oilseed flax and gold-of-pleasure (camelina sativa) are grown. In recent years soya, which is classified by the EU as an oilseed rather than a protein crop, has also been grown in the organic system. Cultivation of oilseed rape in the organic system, despite many attempts, has not been successful, as it requires frequent protective treatments due to the presence of agrophages. The high infestation of oilseed rape by pathogens also eliminates the possibility of cultivation and protection without the use of chemicals. In the organic system the yield of winter oilseed rape is only about 1 t/ha.

The protection of organic crops in the upcoming years will be hindered by the planned withdrawal of copper compounds from plant protection – they are widely used in this production system. The main reason for the future withdrawal of copper compounds is the fact that copper pollutes the environment. Copper is one of the heavy metals and therefore research is currently underway to replace these compounds with other natural substances.

II THE EC BIODIVERSITY STRATEGY IN THE CONTEXT OF PROTECTION AND PRODUCTION OF WINTER OILSEED RAPE

In Poland, the sown area of oilseed rape is approximately one million hectares. Oilseed rape (especially winter oilseed rape) is an agricultural crop which is intensively protected against agrophages, particularly against diseases and over 100 species of pests.

In a way it results from the fact that in the era of breeding work, varieties with good nutritional values appeared on the market. These varieties were deprived of anti-nutritional compounds in the form of e.g. glucosinolates or erucic acid, at the cost of weakening the plant's natural immunity mechanisms protecting them from some pathogens and pests. Despite the fact that breeding progress is constantly introducing new varieties to the market, including varieties characterised by resistance or higher tolerance to certain agrophages (mainly diseases), this resistance is not a permanent feature, as harmful organisms constantly adapt to the environment, including to new varieties. This phenomenon is also facilitated by certain actions undertaken by growers. In addition, the field cultivation of winter oilseed rape takes as long as 11 months, which renders the plant much more vulnerable to negative impacts of agrophages than its spring form.

From sowing to harvesting, oilseed rape is exposed to damage or destruction by various pests that can reduce the quality and quantity of yield. For this reason, the protection of this plant requires a comprehensive approach consisting in both prevention and direct control methods. Since 2014, oilseed rape protection against agrophages has been based on the integrated pest management guidelines, implemented in the EU by Directive 2009/128/EC, as well as subsequent legal acts adopted by individual member states, including Poland. Integrated pest management clearly specifies the measures that the farmer must take in order to reduce the use of chemical plant protection products. The relevant information can be found in Annex III to the above-mentioned Directive, which states, i.a., that the prevention or minimisation of the adverse effects of harmful organisms on cultivated plants may be achieved or promoted through:

- crop rotation;
- appropriate cultivation techniques (e.g. weed control before sowing or planting, compliance with the sowing date and standard, use of undersown crops, no plough tillage, cutting and direct sowing);
- use of resistant or improved/tolerant varieties and standard/certified seed and planting stock;

- balanced fertilisation, liming and irrigation/drainage;
- application of hygiene measures (e.g. regular cleaning of machinery and equipment) to prevent the spreading of harmful organisms;
- protection and establishment of conditions for important beneficial organisms, e.g. by appropriate plant protection methods or the use of ecological structures on and outside the production site.

The use of non-chemical methods is complemented by careful monitoring of pests so that it is justifiable (both economically and environmentally) to use chemical treatments. The guidelines of integrated pest management are also a component of integrated production subject to official controls, which is a certified system of plant production, where it is necessary to adapt the production to the requirements specified in the methodologies approved by the Chief Inspector of Plant and Seed Protection. Methodologies of integrated plant production include elements such as:

- planning and establishing cultivation, taking into account the selection of varieties;
- fertilization, taking into account soil analyses;
- the use of rational methods of weed control;
- crop care;
- protection against diseases and pests, taking into account non-chemical methods;
- hygiene and sanitation rules;
- lists of obligatory activities and treatments in the system of integrated plant production,
- IP checklists, general rules for issuing IP certificates.

The concept of integrated pest management and oilseed rape production allows for rational management of the means of production, however, in the era of changing legal conditions the concept needs to be adapted to the new reality.

One of the main assumptions of the European Green Deal is reducing the use of chemical pesticides by 50% by 2030; it will largely reduce the profitability of production of this crop, given that oilseed rape is susceptible to a range of agrophages, including weed, disease and pest groups. For the time being, the possibilities of rape cultivation ecologisation are very limited and impossible to implement on a large scale, therefore only some of the available solutions allowing to manage the means of production more rationally than it was done in the past can be introduced in this crop. However, the market expectations as to the amount and quality of crops put farmers in a difficult position, especially in the era of changing climate that only increases the risks of certain threats rather than reducing it.

Oilseed rape is one of the three most intensively chemically protected field crops. It is estimated that an average of 1.74 kg is used per 1 ha of cultivation in Poland. Due to its high susceptibility to pests, the plant is not commonly grown on organic farms (which is possible, but results in a significantly lower yield).According to official data collected by the Agricultural And Food Quality Inspection (JIHARS), adding up the certified crops together with crops cultivated on farms going through the process of conversion into organic farming, oilseed rape was grown in this manner in Poland in 2020 on only 1502 hectares, giving a total yield of just under 1480 tonnes.

Due to market expectations, oilseed rape producers are obliged to deliver raw material characterised by the best quality parameters in appropriate quantities, which enforces on them the implementation of careful plant protection.

The Biodiversity Strategy is a part of the so-called European Green Deal. The specific objectives of this strategy include reversing the decline in pollinators, reducing the use of chemical pesticides by 50%, reducing the use of fertilizers by at least 20%, the presence of landscape elements of high diversity on at least 10% of agricultural land, covering at least 25% of agricultural land with organic farming, achieving significant progress in the restoration of sites with contaminated soil.

New EU assumptions will have a significant impact on the production of oilseed rape in Poland, especially given the fact that this plant is susceptible to various biotic and abiotic threats which can reduce the amount of yield as well as its quantity.

Although in Poland only 2.5 kg of active substances of plant protection products are used per 1 ha (the EU average is 3.5 kg/ha), which is one of the lowest average use in the Community in comparison with e.g. the Netherlands, Italy, Portugal, Germany or France, the new strategy forces the introduction of certain limitations in oilseed rape protection against agrophages, which have already taken place and will intensify along with the decreasing number of active substances. Protection of this plant is becoming more and more difficult and in the perspective production costs will increase, including a decrease in yields due to the lack of ecological alternatives.

It will become necessary to develop a new strategy of oilseed rape protection in Poland, taking into account the decreasing possibility of the use of chemical plant protection products and the simultaneous increase in the risk generated by agrophages and the lack of possibility to replace chemical protection with biological means. Even more attention will have to be paid to the protection of pollinators, beneficial organisms and the maintenance of biodiversity in agrocenoses. This can be achieved, by example, through creating ecological sites.

According to the definition adopted by the Convention on Biological Diversity, species diversity means the variability among all living organisms present on Earth in terrestrial ecosystems and the ecological complexes of which they are a part. At least 20 species of plants and fungi are dying off the planet every day as a result of pollution and transformation occurring in their natural habitat. This rate is estimated to increase in the next 30 years to over 100 species per day. The main cause is habitat loss, i.e. the destruction by humans of conditions suitable for the life of given species. Many organisms are virtually unable to live: hide, reproduce, or find food on land seized and transformed by humans. The threat from habitat loss affects more than half of the species that are currently dying out. Another major threat is the introduction by man of species from other geographical areas, the so-called alien invasive species, which displace native species. The diversity in the forms of living organisms results from their ability to adapt to the natural environment in which they live. The transmission of traits to the next generation ensures the survival of species. Thanks to constant evolution, the natural environment is rich in varieties and forms. In the process of evolution, nature produces diversity and sustains it. In contrast, the continued development of individuals with new traits and new combinations of traits increases the likelihood of species survival in the event of subsequent environmental change.

Scientists have identified and described less than two million species of plants and animals, while in fact there are presumably approximately ten million species living on Earth. Taking the above into account, at least 80% of organisms are not even named. These numbers illustrate the biodiversity, i.e. the multitude and variety of forms which the living matter can take. Given the fact that each group of organisms has its specific place and function in the ecosystem, when a particular species becomes extinct, the whole ecosystem is disrupted.

The term “level of biodiversity” refers to ecological systems, the specificity of their species composition and the biological balance that is based on it. Different types of ecosystems have developed when species (and their population sizes) existing under particular environmental conditions adapted to the ecosystem structure. If an ecosystem is destroyed, nature can restore it over a long period of time, provided there is an influx of suitable species from the outside. Destroyed ecosystems which had been very rich in species and had covered large areas cannot be restored. Protection of ecological landscape characteristic for a given area is important not only because of its natural specificity, but also because of its aesthetic values.

The IUCN's Red List of Threatened Species was created to minimize and protect endangered species. This is a register of selected endangered animal species (including insects) of the world. It features a list of dying breeds with detailed descriptions and maps indicating the location of their habitats. It also determines the degree of threat to individual species, the rarity of their occurrence, and the protection methods proposed and used.

THE EC BIODIVERSITY STRATEGY proposes restoring degraded ecosystems on land and at sea by means of increasing production in the organic farming system and increasing the number of nature-friendly elements in the agricultural landscape, as well as halting and reversing the trend of declining pollinator populations and reducing the use of (and, consequently, the associated risks) plant protection products by 50% by 2030 within the framework of the EC Farm to Fork Strategy. Such actions aim at putting the European Union in the global forefront of the fight against the global biodiversity crisis. All external action tools and international partnerships should be mobilized for an ambitious new UN Global Biodiversity Framework, which are to be adopted at the Conference of the Parties to the Convention on Biological Diversity in 2021.

Biodiversity protection has been included in international protection conventions, laws and development programmes of international communities and individual countries. It is one of the priorities of EU environmental policy.

Creating and ensuring the functioning of various forms of nature protection is an important element of achieving the objectives of nature protection in Poland. The forms of environmental protection were established on the basis of the development of scientific background and long practice of national nature protection. Each of the forms plays a different role in the Polish system of nature protection and they serve various purposes. That is why they are subject to different protection regimes and scopes of limitations in utilization.

Woodlands are a refuge of biodiversity, providing shelter for numerous species of birds, bats and insects, both in semi-natural as well as anthropogenic landscape. Therefore, in the integrated pest management, including protection of winter oilseed rape, it is crucial to maintain baulks and farmland woodlots and shrubs, which provide natural shelter and overwintering and breeding grounds for many animal species. Refraining from baulk mowing and maintaining meadows in their natural state significantly contributes to biodiversity in a given area.

As a result, special passageways are created; they facilitate insect movement across agricultural landscapes and constitute a sustainable tool that supports integrated pest management programs. This also applies to agriculture, and in particular to large-scale crops, including winter oilseed rape plantations.

The withdrawal by the EU of many active substances used in plant protection products results in an increase in the use of available preparations due to the growing the number of treatments carried out. This exerts a negative impact on the environment, including on beneficial insects such as ladybirds, ants, carabids and many others. These insects help the farmer to reduce the number of phytophagous in the fields.

The increasing number of available biopreparations containing microorganisms is conducive to enhancing biodiversity. In 2004, there were only 12 such preparations, based on three species of parasitic bacteria and one species of insecticidal virus. The number of such preparations is regularly increasing and by the beginning of 2021 there were already 36 products containing more than a dozen species. In accordance with the applicable Polish and EU regulations, biopreparations containing microorganisms, such as viruses, protozoa, fungi and bacteria, are subject to registration. Preparations containing the macro-organisms such as parasitic nematodes, predatory mites and parasitic and predatory insects do not need to be registered.

When winter oilseed rape plantations are heavily infested with pests and the economic damage threshold is exceeded, biological methods are not sufficient and the grower is forced to use chemical plant protection products. However, with constant monitoring of the plantation in accordance with the recommendations of integrated production, the farmer can apply border or spot treatments, depending on the pest population and its size. According to research and experience gathered as a result of many years of observation, it is known that plantation colonization starts from the plantation border area. Carrying out such treatments reduces not only the farmer’s working time, but also effectively limits the costs of preparations used and reduces the negative impact on the environment, which is in line with the integrated protection of plants and EC Strategies.

Biodiversity loss is caused by i.a. overexploitation of natural resources, habitat loss, pollution and climate change, and is a major global concern. This is because sustainable production systems and food security depend on the proper functioning of the ecosystem, which cannot exist without biodiversity. It is important to recognize that damaged ecosystems are more vulnerable and have a reduced capacity to cope with incidents of extreme nature and new agrophages. Sustainable ecosystems protect against unpredictable agrophage infestations that cause economic losses.

As a result of unsustainable human activities, the global population of wild species has declined by 60% over the past 40 years. Approximately one million species can become extinct in the next few decades. These losses are mainly the result of conversion of natural habitats to agricultural land and urban development. The term "biodiversity" became one of the most widely used terms in science and beyond in the late 1980s; the word perfectly illustrates the incredible richness of the natural world. The concept of biodiversity became the main paradigm of ecology, modern nature protection and environmental policy. This means that in order to maintain properly functioning ecosystems, it is necessary to act in such a way and to implement such actions that will protect life at all possible levels of its organization (genetic, generic and ecosystemic). Biodiversity is important because it is closely linked to ecosystem stability.

One of the objectives of the Farm to Fork Strategy is to restore at least 10% of farmland featuring landscape elements characterised by high diversity. These include, but are not limited to: buffer zones, fallow lands, hedgerows, non-productive trees, partition walls and ponds. These are elements that increase carbon sequestration, prevent erosion and soil depletion, filter air and water, and support the process of adapting to the changing climate. The strategies also pertain to organic farming, which by 2030 should constitute at least 25% of agricultural land in EU countries. It is also important to protect soil fertility, reduce soil erosion and increase the content of organic matter in soil.

In the agroclimatic conditions of Poland winter oilseed rape is attacked by more than 100 pests, most of which are of economic importance. Pending climate changes and the withdrawal by the European Commission of various active substances used in plant protection products render the situation even more difficult. Existing plant protection methodologies should be reviewed so that new plant protection strategies, allowing for non-chemical (including biological) methods of plant protection could be developed.

The Biodiversity Strategy enforces a reduction in the use of chemical plant protection products, and, what is perhaps the most important, directs our attention to the environment in which we live. Biological agents such as beneficial micro- (fungi, bacteria) and macro-organisms (entomophages, insecticidal nematodes) are part of this environment and, under favourable conditions, often reduce pests and causes of disease to levels below the damage threshold. Measures must be taken to support the effectiveness of beneficial organisms in the agricultural environment. It is essential that farmers initiate appropriate measures ensuring sustainable use of the landscape. Initiatives aiming at diversification of the landscape should be promoted through the preservation or creation of such elements as: ponds, baulks and farmland woodlots, which provide habitats, place for development, shelter and food for many animal species. The use of biological methods against agrophages includes using a conservation method to modify the agricultural landscape by humans to create suitable conditions for the development of beneficial organisms in the environment. In addition to the previously mentioned, they also include: planting melliferous plants, using appropriate agrotechnology and many others. Planting dill, coriander or cumin provides a continuous source of valuable flowers on which beneficial organisms feed. Such activities contribute to the maintenance of biodiversity in the agricultural environment.

The EC Biodiversity Strategy is also expected to reverse the decline in pollinator insect populations, which is important for winter oilseed rape production. It is a plant that is visited by a large number of pollinating species, among which honeybees are predominant. The European Commission's action proposing that 10% of agricultural land should be high-diversity landscape features, for instance in the form of hedges or flower strips, is of great importance when we consider the needs of beneficial organisms.

Certified Integrated Production supports biodiversity as well. One of its principles indicates that biological and other non-chemical methods of plant protection should be preferred over chemical methods of pest control (assuming that they provide protection). Also, the National Action Plan for Reducing the Risks Associated with the Use of Plant Protection Products for 2018 - 2022 (M. P. of 2018, item 723), promotes non-chemical methods of plant protection, which leads to a reduction in the dependence of plant production on chemical plant protection products and, as a result, reduces the risks associated with their use.

Here it should be stressed that biological methods do not combat populations of agrophages as chemical plant protection products do, but only reduce populations of harmful organisms over a longer period of time.

III INTEGRATED PEST MANAGEMENT OF WINTER OILSEED RAPE

III.1. CURRENT AND FUTURE THREATS

The growing acreage of winter rape cultivation, intensification of production, application of simplified agrotechnology, cultivation of varieties with diverse susceptibility and tolerance to agrophages, in connection with agroclimatic changes (growth period longer by more than a month) – these are the main factors that may limit the yield and impair its quality as a result of pest feeding.

In Poland, winter oilseed rape can be damaged by about 25 pest species of economic importance (Table 1-5). On average, common pollen beetle and stem weevils reduce the yield of winter oilseed rape by more than ten percent. Furthermore, losses in seed yield caused by all agrophages may amount to 50%; in extreme cases they may cause total destruction of the plantation. In the 1980s and 1990s, the most important pests of winter oilseed rape in Poland were mainly beetles – common pollen beetle, Ceutorhynchus napi and Ceutorhynchus pallidactylus. At present, the observations show that there is an increase in the threat of oilseed rape from aphids (green peach aphid and cabbage aphid), scale pests (Ceutorhynchus assimilis and brassica pod midge), cabbage fly, Ceutorhynchus pleurostigma, cabbage leafminer, the diamondback moth, whiteflies and slugs. Growing threats to winter oilseed rape crops from certain pestsresult mainly from the application of simplified agrotechnology, increased cultivation area, shorter time between subsequent crop rotations, as well as agroclimatic changes, i.e. increased air temperature and lack of cold winters.

The above factors, coupled with anthropopressure in wildlife refuge sites also result in changes in wildlife biology and behaviour. The noticeable increase in the number of deer, wild boar and some bird species is a threat to oilseed rape crops, especially winter rape. Winter oilseed rape is a source of nutrition for roe deer, fallow deer, red deer and wild geese in autumn and winter; after the start of growth period in spring it becomes a refuge for red deer and wild boar. In areas bordering forests and other habitats where game mammals reside, oilseed rape crops are particularly vulnerable to destruction. Winter oilseed rape crops located along migration or overwintering routes of wild geese are also severely damaged. Forecasts for the future are hardly optimistic, as population control of these animals is limited and crop protection methods, apart from building permanent fences, are not very effective. Climate change also contributes to periodic explosions of rodents population, field mice and common voles (in the wild – three to five generations per season), reproducing from March to October (house mouse, under favourable conditions, reproduces throughout the whole year, producing ten litters). The pregnancy lasts about 20-21 days, and the female gives birth to 4 to 9 young (sometimes even 12) each time. Eight-week-old field mice and common voles are already sexually mature. These animals lead terrestrial lifestyle, both diurnal and nocturnal. They can be found in many habitats, including winter oilseed rape crops, feeding on the roots and green parts of plants. As it was mentioned above, in favourable periods and areas which are suitable for mice and voles, there may be several tens of thousands of these animals per hectare, which translates into high yield losses of oilseed rape.

TABLE 1. Economic importance of pests of winter oilseed rape in Poland

Pests	Potential threat		Pests	Potential threat	
	currently	in the future		currently	in the future
Pieridae	+	++	Nematodes	+	++
Ceutorhynchus napi	++	+++	Cabbage-stem flea beetle	+++	+++
Ceutorhynchus pallidactylus	+++	+++	Flea beetles	++	+++
Ceutorhynchus pleurostigma	+++	+++	Scarabaeidae	++	++
Ceutorhynchus assimilis	+++	+++	Brassica pod midge	+++	+++
Baris	+	++	Black cutworm	++	+++
Wireworms	++	++	Common pollen beetle	+++	+++
Turnip sawfly	++	+++	Slugs	++	+++
Rodents	++	+++	Cabbage fly	+++	+++
Cabbage whitefly	++	+++	Diamondback moth	+++	+++
Cabbage leafminer	++	+++	Thrips	+	+++
Cabbage aphid	++	+++	Game animals and birds	++	+++
Green peach aphid	+++	+++			

+ pest occurring only locally, therefore posing a minor threat

++ pest posing a considerable threat

+++ pest posing a major threat

TABLE 2. Crucial biological traits of winter oilseed rape pests

Pest	Size of the imago (mm)	Harmful stage	Overwintering stage	Place of overwintering	Number of generations	Host plants
Large white	50*	larva	chrysalis	by tree trunks, etc.	2	mustards
Small white	40*	larva	chrysalis	on soil	2	mustards
Ceutorhynchus napi	3–4	larva	imago	soil	1	mustards
Ceutorhynchus pallidactylus	2.5–3	larva	imago	soil	1	mustards
Ceutorhynchus pleurostigma	2–3	larva	larva / coleopteran	galls/soil	1	mustards
Ceutorhynchus assimilis	2.5–3	larva	imago	soil	1	mustards
Baris	3–4	larva	coleopteran	soil	1	mustards
Wireworms	7–15	larva	larva, imago	soil	1 (3-5 years)	polyphage
Turnip sawfly	6–8	larva	larva	soil	1–2	mustards
Cabbage whitefly	1.5	larva, imago	imago	mustards	4–5	mustards, Papaveraceae
Cabbage leafminer	2–3	larva	chrysalis	soil	3	mustards
Cabbage aphid	2–3	larva, imago	Eggs	mustards, weeds	more than ten	mustards
Green peach aphid	2–3	larva, imago	Eggs	peach	more than ten	polyphage
Cabbage-stem flea beetle	3–4	larva	imago	soil	1	mustards
Flea beetles	2–3	larva, imago	imago	soil	1	mustards
Scarabaeidae	10–30	larva (imago)	larva, imago	soil	1 (2–5 years)	polyphage
Brassica pod midge	1.5	larva	larva	soil	2–3	mustards
Black cutworm	35–50*	larva	larva	soil	1–2	polyphage

TABLE 2. Crucial biological traits of winter oilseed rape pests; cont.

Pest	Size of the imago (mm)	Harmful stage	Overwintering stage	Place of overwintering	Number of generations	Host plants
Common pollen beetle	1.5–2.5	larva, imago	imago	woodland edges	1	mustards
Slugs	45	imago	eggs, imago	soil	1–2	polyphage
Cabbage fly	5–6	larva	chrysalis	soil	3	mustards
Diamondback moth	15–18*	larva	chrysalis / butterfly	weeds /under the bark	2–4	mustards
Thrips	1–2	larva, imago	larva, imago	soil	1	mustards

* wingspan

TABLE 3. Damage to underground parts of oilseed rape plants caused by pests

Pest	Damage description
Ceutorhynchus pleurostigma	One or more round, smooth-walled galls of about 1 cm in diameter can be found on the root collar or root. Inside the gall, when cut, a larval gallery and a *Ceutorhynchus pleurostigma* larva can be seen.
Baris	Hollow galleries and passages can be found in the root and root collar.
Wireworms	Damage to the root system – bitten off lateral roots and biting of the main root.
Rodents	Damage to the root system – biting plants while digging burrows under them. Leaf and stem damage is also observed – especially in the early stages of oilseed rape development.
Nematodes	Stunted plants, poor growth, with leaves bending and wilting. Distortions and balls – nematode cysts – can be observed on the roots.
Scarabaeidae	Damage to the root system – bitten off lateral roots and biting of the main root.
Black cutworm	Plants are bitten near the root collar, causing them to be severed from the roots. Some of them are pulled into holes previously made in the soil by the caterpillars. Occasionally, leaf feeding can also be observed.
Cabbage fly	There is brown discoloration on the root collar and roots, as well as over-rotted areas. The lateral roots are partially dead and it is hard to tell whether they are even present when extracting plants out of the ground. In the outer layer of the root, as well as inside the root collar, there are galleries of dead tissue in which the larvae of the cabbage fly feed.

TABLE 4. Damage to aboveground parts of oilseed rape plants caused by pests

Pest	Plant damage description
Pieridae	Biting holes in the leaf blade. Older, more voracious caterpillars may skeletonize leaves.
Ceutorhynchus napi	The first symptoms are “prick” spots on the stem about 1 mm in size, initially slimy, then with white rims. On the stem, as the main shoot grows, the mutilated areas elongate and form thin channel, thickenings, and S-shaped curvatures, primarily in the lower part of the stem. In these areas, the stems snap, often break and provide an entry gate for diseases. Traces of feeding larvae can be identified in the stem core.
Ceutorhynchus pallidactylus	The first signs of the pest's presence are “pricks” on the main leaf veins and petioles, made by the females to lay eggs. Inside the stem, whitish larvae feed in brown galleries (galleries stained by droppings). In contrast to the damage caused by the *Ceutorhynchus napi*, the oilseed rape stem continues to grow straight (there is no deformation of the stem during growth). During severe stem damage, stunted plant growth may occur.
Ceutorhynchus assimilis	Pods remains closed, but yellow prematurely and are slightly deformed and with 1 hole. Inside the pod 1 larva can be found, feeding on the seeds.
Turnip sawfly	On the underside of the leaves, the tissue is scraped by young larval stages and small holes in the leaf blade can be seen. Later there are defoliations caused by older larval stages, whole leaves are eaten, only the main veins, inflorescences and pods remain.
Rodents	Bitten roots and green parts of plants
Cabbage whitefly	The affected plant parts are stunted in their development; under conditions of moisture deficiency they turn yellow and dry out. In the case of an abundant population in the autumn, growers could therefore be concerned about a poorer preparation of oilseed rape for overwintering. Viral Vector.
Cabbage leafminer	On petioles and leaf blades, mines can be observed as a result of the larvae eating the ground tissue under the epidermis. The mines contain small, whitish legless larvae.
Cabbage aphid	Dense colonies of wax-covered aphids occur on the apical part of the main flower shoot and later on the lateral shoots. They are also found on petioles and pod shacks, as well as pods and leaves. The affected plant parts are stunted in their development; under conditions of moisture deficiency they turn yellow and dry out.
Green peach aphid	Occurs on leaves during the fall growing season. The affected plant parts are stunted in their development; under conditions of moisture deficiency they turn yellow and dry out. Turnip mosaic virus vector.
Cabbage-stem flea beetle	Cotyledons and leaves show typical symptoms of feeding (holes and skeletonization of leaves).The large population means that leaves can be perforated. More significant are the mines on petioles, leaf veins, and stem. Brown powder or dirty white larvae can be found in the galleries.

TABLE 4. Damage to aboveground parts of oilseed rape plants caused by pests; cont.

Pest	Plant damage description
Flea beetles	On young leaves, cotyledons, and even on the sprouts of emerging plants, small, round eating holes about 1 mm in diameter can be seen. Damaged cotyledon tissue loses water rapidly and the plant dries within 2-3 days. The sprouts are destroyed even before they reach the surface.
Brassica pod midge	Pods prematurely turn yellow, swell, often become distorted near the top, shrink and crack prematurely. Inside the pods there are numerous larvae (5 to 100) that destroy the seeds.
Common pollen beetle	Eating holes in flower buds, some completely hollowed out. Damaged buds turn yellow, wither and fall off, leaving only the pedicels. This results in irregular inflorescences, or irregularly spaced pods.
Slugs	After emergence the seedlings are eaten in whole or cut down by slugs just above the soil surface.
Diamondback moth	Numerous small, roundish or irregular holes can be found on the leaves after the caterpillars have scraped off the lower epidermis and ground tissue. Upper epidermis as the leaf grows, it cracks and holes form.
Thrips	Yellowing and other discoloration on the surface of the pods.
Game animals and birds	Biting down and even eating whole plants during emergence (birds) and at later stages of development (game).

TABLE 5. Economic damage thresholds for winter oilseed rape pests

Pest	When observed	Damage threshold
Ceutorhynchus napi	early March and late March	10 beetles in a yellow bowl over subsequent 3 days or 2–4 beetles on 25 plants
Ceutorhynchus pallidactylus	at the end of March and at the beginning of April	20 beetles in a yellow bowl over subsequent 3 days or 6 beetles on 25 plants
Ceutorhynchus assimilis	at the end of April and at the beginning of May	4 beetles on 25 plants
Turnip sawfly	September and October	1 caterpillar per plant
Cabbage aphid	from the beginning of the pod development	2 colonies per 1 m^2 on the field edge
Flea beetles	September and October	1 beetle per 1 linear metre of the row
Brassica pod midge	from the beginning of petal fall	1 imago per 4 plants
Common pollen beetle	compact inflorescence	1–2 beetles per plant
	loose inflorescence	3–5 beetles per plant

TABLE 5. Economic damage thresholds for winter oilseed rape pests; cont.

Pest	When observed	Damage threshold
Slugs	immediately after sowing and during emergence (BBCH 08–11)	2–3 snails on average per trap, 5% damage
	in 1–4 leaf stage and later stages (BBCH 11–15)	4 or more snails on average per trap, 10% severe or very severe damage of plants
Cabbage fly	September-November	1 fly in a yellow dish in 3 days

III.2. WITHDRAWN ACTIVE SUBSTANCES

The withdrawal of active substances of plant protection products, including insecticides, causes problems in controlling the population of many harmful insect species of winter oilseed rape crops and necessitates the search for new, alternative solutions (Table 5). Particular attention should be paid to continuous monitoring of the level of susceptibility of pests to the active substances available for use. With the limited number of plant protection products available, the implementation of the basic principle of resistance prevention strategies, which is the rotation of insecticides with different modes of action (Table 6), faces new, serious problems. An important element of protection is therefore the skilful use of safe and at the same time effective insecticides, adapted to the current situation, as well as the search for new, safe chemical substances and biological agents.

TABLE 6. Mode of action, chemical groups and active substances of insecticides recommended for winter oilseed rape

Chemical group	Active substance	Mode of action	IRAC classification
Organophosphates	Phosmet	blocking acetylcholinesterase	1B
Pyrethroids	alpha-cypermethrin beta-cyfluthrin cypermethrin deltamethrin esfenvalerate gamma-cyhalothrin lambda-cyhalothrin tau-fluvalinate zeta-cypermethrin	prolonging the opening of sodium channels	3A
Aryl propyl ether	Etofenprox		
Neonicotinoids	Acetamiprid	substitution of acetylcholine at postsynaptic receptors	4A
Oxadiazines	Indoxacarb	blocking sodium channels in nerve cells	22A
Diamides	cyantraniliprole	activation of calcium channels in nerve and muscle cells	28

Insecticide active substances withdrawn from winter oilseed rape protection in recent years: chlorpyrifos, clothianidin, thiamethoxam, imidacloprid, thiacloprid, beta-cyfluthrin (until 20 July 2021), alpha-cypermethrin (until 7 December 2022).

III.3. SUBSTITUTES FOR WITHDRAWN ACTIVE SUBSTANCES

The EU enforces the withdrawal of numerous active substances, however, it does not suggest any new solutions, which is a problem for winter oilseed rape growers. Table 7 provides substitutes for the withdrawn active substances that growers can use.

Insecticide active substances to be replaced (withdrawn) from winter oilseed rape cultivation: esfenvalerate, lambda-cyhalothrin, gamma-cyhalothrin, etofenprox, phosmet, indoxacarb.

TABLE 7. Substitutes for withdrawn active substances in winter oilseed rape

Pest	Active substance
Ceutorhynchus napi	acetamiprid, deltamethrin, tau-fluvalinate, zeta-cypermethrin
Ceutorhynchus pallidactylus	acetamiprid, cypermethrin, deltamethrin, tau-fluvalinate, zeta-cypermethrin
Ceutorhynchus assimilis	acetamiprid, cypermethrin, deltamethrin, tau-fluvalinate, zeta-cypermethrin
Turnip sawfly	acetamiprid, cyantraniliprole, deltamethrin
Whiteflies	not present
Aphids	acetamiprid, deltamethrin
Cabbage-stem flea beetle	*Bacillus amyloliquefaciens,* acetamiprid, cyanotraniliprole, cypermethrin, deltamethrin, flupyradifurone
Flea beetles	*Bacillus amyloliquefaciens,* cyanotraniliprole, deltamethrin, flupyradifurone
Brassica pod midge	acetamiprid, deltamethrin, tau-fluvalinate, zeta-cypermethrin
Common pollen beetle	acetamiprid, cypermethrin, deltamethrin, tau-fluvalinate, zeta-cypermethrin
Cabbage fly	acetamiprid, cyanotraniliprole, cypermethrin, deltamethrin, flupyradifurone
Diamondback moth	not present

III.4. SCOPE FOR USING BIOLOGICAL METHODS

Biological methods of oilseed rape protection against pests are very limited due to the fact that in Poland there are no registered bioinsecticides.

So far, a biopreparation Integral Pro from the group of biological fungicides has been registered for seed treatment of oilseed rape, the active substance of which is *Bacillus amyloliquefaciens* strain MB1600. It is used for the purpose of protecting of oilseed rape against stem canker. However, the product also acts as a stimulant of natural plant defence mechanisms, thus reducing damage caused by flea beetles occurring in oilseed rape. The measure may have a variable level of action. Therefore, satisfactory efficiency cannot be expected in all cases. The maximum recommended dose is 160 ml per 100 kg of seed, recommended amount of water: 10–20 ml per 1 ml of the product.

In the absence of registered bioinsecticides, biological methods can only be used as a supplement to other protection methods: agrotechnological and breeding methods. The scope of available biological methods of oilseed rape protection against pests is very limited due to the fact that in Poland there are no registered bioinsecticides. The use of biological methods against agrophages includes using a protection method to modify the agricultural landscape by humans to create suitable conditions for the development of beneficial organisms in the environment. Under natural conditions, beneficial organisms play a huge role in the process of regulating pest population. These include predatory insects which kill and eat individuals of another species; parasitic insects, which use the host organism continuously or periodically as a food source and habitat; and parasitoids, which are parasites whose larvae kill their hosts and whose adult forms do not need a host to live. Beneficial organisms also include viruses and insecticidal microorganisms (fungi and bacteria).

The EC *Biodiversity Strategy for 2030* and the *Farm to Fork* Strategy aim at reducing the use of chemical plant protection products and ensuring that sufficient attention is paid to environmental protection. Biological agents, i.e. beneficial micro- and macro-organisms are part of this environment. Therefore, human activities directed to support the role of beneficial organisms in nature are of great importance in the process of implementation of the above-mentioned strategies. Also assumptions of the Common Agricultural Policy for 2021-2027 promote initiatives aiming at diversification of the landscape through the preservation or creation of such elements as: ponds, baulks and farmland woodlots, which provide habitats, place for development, shelter and food for many animal species.

The importance of beneficial ground beetles in integrated pest management is continuously increasing. They can be found in all agricultural environments, including in winter oilseed rape crops. Due to their large size, high mobility and great voracity, they are counted among the most effective beneficial insects which significantly reduce the number of many plant pests. Ground beetles can cause a 50% reduction in the population of chrysalis of the common pollen beetle (*Meligethes aeneus* L.) and reduce the population of numerous oilseed rape pests belonging to the beetles, *Hymenoptera* and butterflies. The ground beetle species such as the *Clivina fossor* cause 60–65% of deaths of the common pollen beetle and the *Ceutorhynchus assimilis*. In other countries, the effectiveness of ground beetles may vary. In Finland for instance, only a 3% reduction in the population of common pollen beetle larvae was observed on spring oilseed rape. In Sweden, no significant activity of pollinators against the common pollen beetle was observed, whereas in Germany approximately 50% of the common pollen beetle larvae are eaten by pollinators. In order to ensure high effectiveness of pests reduction, it is good to cultivate oilseed rape near forests, as they provide habitat for ground beetles.

The withdrawal of neonicotinoid seed treatments and many foliar insecticides by the European Union causes problems with winter oilseed rape pests during autumn growth period protection. During autumn growth period, winter oilseed rape can be attacked by: cabbage fly, flea beetle, *Ceutorhynchus pleurostigma*, cabbage-stem flea beetle, turnip sawfly, cabbage aphid, black cutworms and cabbage whitefly. Under natural conditions, aphid populations are reduced by predatory insects such as ladybirds (*Coccinellidae*). One larva can eliminate 100 to 200 aphids during its entire development (around 30 days). The beetle can eat 30–250 aphids per day, which is a lot, however, one must remember that aphids develop very fast as well. Taking into account the fact that aphid infestation usually occurs earlier than the infestation of ladybugs and other beneficial insects, the farmer must decide whether or not to use a chemical plant protection product. If such treatment is necessary, it should be carried out as early as possible, before the natural enemies of aphids arrive at the field or should be limited to plantation marginal strips or even to spot treatments; it should be carried out with the use of a selective insecticide. Another species that eat aphids are net-winged insects (*Neuroptera*). The larva of the *Chrysopa carnea* can eat up to 400 aphids. However, despite their great efficiency in killing aphids, the high mobility of these insects limits the possibility of controlling their populations (both natural and artificially introduced) to a large extent.

The features of agricultural environment influence the occurrence of parasitic and predatory insects. The research conducted at the Field Experimental Station Winna Góra (functioning under Institute of Plant Protection – National Research Institute) showed that the greatest number of flies was caught on the mid-field roads. Large numbers of these individuals were also spotted on baulks; the same applies to most species of insecticidal fungi. It is a common knowledge that hoverflies larvae (predatory stage) feed mainly on aphids and their presence in the environment is extremely important. Adult forms feed on pollen and flower nectar, therefore leaving enclaves of wild plants or deliberate sowing of melliferous plants (e.g. *phacelia*, buckwheat, borage), which provide hoverflies and other beneficial insects with food necessary for their development, is also an action aiming at supporting their effectiveness in the field. Apart from hoverflies, aphid populations can be limited thanks to larvae of flies from the gall midges family, mainly the aphid midge (*Aphidoletes aphidimyza* R.) and larvae of *Chrysopa carnea* L. In addition to ladybirds, parasitic *Hymenoptera* from the *Ichneumon* wasps and *Chalcididae* families are of great importance, e.g. the parasitoid diamondback moth, *Hymenoptera Diadegma fenestralis*, which controls more than 90% of the caterpillars and is one of the most important organisms limiting the population of the diamondback moth. Cabbage white butterfly caterpillars are destroyed mainly by the *Hymenoptera* white butterfly parasite (*Apantheles glomeratus* L.), which destroys about 90% of the white butterfly caterpillar population. Cabbage fly chrysalises are destroyed by the larvae of *Aleochara Bilineata Gyllenhal*, a parasite of *Staphylinidae* family. These are predatory species, which are very voracious. They feed mostly in soil and bedding, like to hide and are not easily spotted in agricultural environments. However, by feeding on many species of harmful insects, they efficiently and naturally contribute to maintaining the balance in the environment.

There are several hundred species of *Hymenoptera* in oilseed rape crops, 70 of which are parasitoids that attack pests. They are one of the most important factors in the process of limiting the number of many winter oilseed rape pests. Death rate of common pollen beetle larvae due to their natural enemies can be up to 70%. A very high death rate (60-90%) of *Ceutorhynchus assimilis* is caused by *Trichomalus perfectum*.

The most important pests of oilseed rape are host to over 88 species of parasitoids. The common pollen beetle is attacked by 9 species of larval parasitoids; there is no information on the egg parasitoids. *Ceutorhynchus assimilis* is attacked by 34 species of parasitoids, while *Ceutorhynchus pallidactylus* and *Ceutorhynchus napi* are attacked by 8 species of parasitoids.

Insecticidal nematodes (macroorganisms that do not require registration) also prove useful. Positive results have been obtained in Europe (Finland, Germany) following their application to soil, however, application methods need to be perfected. The nematodes are effective against *Ceutorhynchus* and other insects (flies, turnip sawfly) developing or transforming in the soil. In Finland, the insecticidal nematode *Steinernema feltiae* reduced 50% of the populations of common pollen beetle and *Ceutorhynchus*. Research conducted by Institute of Plant Protection – National Research Institute shows that oilseed rape is a crop that perfectly supports the prolonged persistence of insect nematodes in the soil. The nematode *Phasmarhabditis hermaphrodita* is effective against snails. A commercial agent may be too expensive to apply to large areas, however, application methods need to be perfected.

The effectiveness of insecticidal fungi in soil is influenced by cultivation technology.

In no plough tillage cultivation of oilseed rape, over 67% death rate of greater wax moth larvae was observed in June, while in ploughed cultivation only over 42% death rate was observed. No plough tillage promotes the development of insecticidal fungi. It is believed that winter oilseed rape is a crop which does not tolerate simplified tillage and usually reacts with a significant decrease in yield. This opinion was conceived in the time when available no plough tillage technologies were limited to surface tillage of the entire field with disc harrow, tiller or direct sowing with no tillage at all. As far as the sowing technique is concerned, these technologies are quite demanding as the drill works in soil covered with plant residues.

Oilseed rape is a particularly demanding crop in this respect and even in conventional cultivation, when the field is cleanly prepared for sowing, the quality of the crops is often not satisfactory already at the emergence stage. Very small seeds require surface sowing as well as a good cover and contact with moist soil. In conventional cultivation, a large number of heavily spraying treatments carried out in a short period of time dries the soil; as a consequence after heavy rains the soil becomes crusted, which makes it impossible for plants to emerge. No plough tillage reduces tillage erosion of the soil and increases the amount of water retained in the soil, especially if a lot of mulch is left on the field surface. Such technologies also have no adverse effect on beneficial microorganisms.

Under favourable conditions (high humidity and temperature above 20°C), insecticidal fungi belonging to the *Entomophthora muscae* group play a major role. These fungi can cause epizootics, i.e. mass die out of aphid colonies. The development of insecticidal fungi is favoured by water habitats, highly humid habitats, forests, woodlots, rushes and meadows.

Forests are more than twice as rich in insecticidal fungi species as agroecosystems.

In Finland pathogens occurring on pests of oilseed rape have been described. These included insecticidal fungi, insecticidal nematodes, bacteria and protozoa. Among the insecticidal fungi, the species *Beauveria bassiana* reduced the populations of overwintering stages of common pollen beetle. The species *Metarhizium anisopliae* in the soil environment reduced the stages of the cabbage-stem flea beetle, *Ceutorhynchus assimilis* and the common pollen beetle. They caused up to 80% reduction of the population of these pests. One method of introducing an insecticidal fungus into the environment is to use a bee sprinkled with dry spores of the fungus *M. anisopliae* to spread them in the common pollen beetle population. A 61% death rate of the common pollen beetle populations occurring on winter oilseed rape and

99% death rate of populations occurring on spring oilseed rape was achieved. In contrast, the *Bacillus thuringiensis* insecticidal bacterium tested in Finland was not effective against the common pollen beetle. Unfortunately, the above-mentioned bioinsecticides are not registered for oilseed rape pest control in Poland.

In Finland, a strategy has been developed to maximise the use of biological agents for control of the common pollen beetle in oilseed rape cultivation. The strategy involved the following actions:

- refraining from ploughing the field after oilseed rape harvest (parasite management),
- refraining from using chemical insecticides,
- undersowing or intercropping with clover (it is an alternative host for *Sitona* sp., on which insecticide nematodes develop),
- crop rotation,
- introduction of fungi and insecticidal nematodes,
- the use of trap crops and bees carrying spores of the insecticidal fungus to populations of common pollen beetle occurring in oilseed rape.

Pollinators are a very important group of species visiting oilseed rape crops. In addition to bees, oilseed rape plants are also pollinated by hoverflies (*Syrphus* sp.), bumblebees (*Bombus*), the *Halictidae* and the *Megachilidae*. It is a plant that is visited by a large number of pollinating species, among which honeybees are predominant; they are supported by wild bees. These insects are not attacked by beneficial organisms, however, they may be attacked by diseases caused by i.a. protozoa. Insecticidal fungi are also safe for pollinating insects. The protection of bees during plant protection treatments against agrophages is a statutory obligation and results from the provisions of the Act on Plant Protection of 13 February 2020 (Journal of Laws of 2021, item 256). In 2018, Poland was ranked 3rd in the EU in terms of bee colonies with a share of 9.3% in their total number. Spain and Romania had more bees. As far as the production of honey is concerned, Poland was ranked 4th in the EU after Romania, Germany and Hungary.

At present it is not possible to ensure protection of winter oilseed rape with the use of biological agents alone. The conservation method can only serve as a supplement to biological agents. The winter oilseed rape protection strategy must include a set of measures that are based on different methods and must aim at striving to minimize the use of chemical plant protection products. Although the range of available biological plant protection products for field crops is quite limited, the current EC Strategies "Farm to Fork", Biodiversity Strategy and "European Green Deal", as well as "Integrated Pest Management" launching some new products on the market. Preparations based on microorganisms require registration, but products acting against macroorganisms such as insecticidal nematodes are not subject to the registration process, however, they are rarely used in field crops due to their considerable dispersal capabilities. Many countries in Europe, however, have achieved success in using these agents, so it is important to continue and expand research within this field. The average usage of chemical insecticides in winter oilseed rape is 0.28 kg p.p./ha, the total usage of all plant protection chemicals in winter oilseed rape is 1.74 kg p.p./ha. The introduction of bioinsecticides would further reduce the chemicalisation of this crop. However, this depends on the manufacturers of plant protection products and the registration process itself, which is time-consuming and costly. Such problems are one of the reasons for the lack of interest in their use in plant protection.

III.5. AGROTECHNOLOGY AND PESTS

When the range of available active substances is limited, non-chemical methods of crop protection become more important (Table 8). Acting in accordance with the basic agrotechnological recommendations is essential for ensuring effectiveness of integrated pest management programmes at early stages of winter oilseed rape growth. An increase in the area winter oilseed rape cultivation, intensification of production, agrotechnological simplifications, cultivation of varieties with lower tolerance to agrophages, agroclimatic changes (higher temperatures and mild winters result in a longer growth period), and finally limitations in the number of active substances of insecticides are factors which may influence

the quantity and quality of the yield. During autumn growth period, winter oilseed rape is exposed to damage caused by pests from the moment the seeds begin to germinate. At this stage , polygynous soil pests – *Scarabaeidae*, black cutworms, wireworms and *Bibionidae* – are the source of greater danger. This is also applicable to field rodents, especially in plantations where usage of agrotechnology has been reduced. They can feed on germinating seeds causing seedling death and then bite young plants, damaging the root system and shoot base. The underground parts of plants are also damaged by larvae of the cabbage fly, which is currently considered the most dangerous pest of winter oilseed rape. Its larvae feed on roots and the root collar, where they bore passageways. Oilseed rape roots are also damaged during autumn growth period by *Ceutorhynchus pleurostigma larvaeand* field rodents. On the other hand, young leaves, cotyledons and shoots are damaged by flea beetles – cabbage-stem flea beetles and ground flea beetles as well as game mammals, wild geese and swans. The above-mentioned pests, as well as the larvae of the last generation of the diamondback moth and the larvae of the cabbage leafminer, as a result of intensive feeding may significantly reduce the assimilative area of leaves. Aphids have been a big problem in autumn protection of oilseed rape in recent years – cabbage aphid and especially the peach aphidwhich is an effective vector of turnip yellows virus. Recent years have also seen mass appearances of the cabbage whitefly. On the other hand, oilseed rape emergence under conditions of increased moisture can be hindered by slugs. Damage to winter oilseed rape during emergence and first leaf development means an increased risk of secondary infections by disease vectors and poorer plant preparation for winter.

Integrated pest management is based on the use of all available methods, which reduce the use of chemical plant protection products to a minimum. This system of protection makes it possible for farmers to regulate the number of pests to a level below the economic threshold, i.e. not endangering the crop, as opposed to all other methods that prevent mass occurrence of pests by their total destruction. It is particularly important to develop pro-ecological principles of winter oilseed rape plant protection against agrophages, especially in the view of the fact that all attempts to solve phytosanitary problems based only on the chemical method have become unreasonable and less effective. Proecological principles and methods for protection of winter oilseed rape crops against agrophages include agrotechnological methods, which are an element of appropriate protection and production of winter oilseed rape.

Simplified agrotechnology, which is becoming increasingly common, can lead to an increase in the number of pests– especially those which feed or overwinter in the soil. Shallow tillage, no plough tillage and restricted crop rotation are factors that increase the likelihood of increased population of pests in plantations. The development of oilseed rape is influenced by many factors, the most important of which are: the type of preceding crop, the abundance of assimilable substances, condition of soil bacteria culture, the type of cultivation practices and the manner in which they are implemented. Choosing the right site for oilseed rape cultivation contributes significantly to a high yield. Above all, winter oilseed rape should not be cultivated after spring oilseed rape or other brassica plants, particularly due to the threat from cabbage fly. Practice shows that for phytosanitary reasons winter oilseed rape should not be grown in the same field more frequently than every 4 years. From the point of view of plant protection, perennial plants of the legume family, e.g. medick, are considered to be the best preceding crops for winter oilseed rape. In Poland, oilseed rape is grown mainly after cereals, i.e. after the weakest preceding crops. Frequent cultivation of winter oilseed rape following the cultivation of cereals is profitable for organizational, natural and economic reasons, especially due to high share of cereals in the sowing structure – the situation is similar in other European countries.

Pre-sowing treatment significantly reduces the threat of soil pests in particular; overwintering stages of other pests are also destroyed – some mechanically or through drying out, while some are eaten by predatory insects, insectivorous rodents or birds. These treatments also reduce damaging of economically important small field rodents. It is worth mentioning that a sufficiently large spatial isolation between the current and last year's oilseed rape plantation significantly reduces the cost of control of most pest species. On the other hand, the reduction of weed infestation and weed residues, as well as self-seeding oilseed rape, reduces the occurrence of i.a. the diamondback moth, whitefly and slugs. It is also important to remember to conduct shallow tillage immediately after harvest and deep tillage in autumn. Balanced fertilization improves the health of plants, which – by developing in optimal conditions – can more easily regenerate any damage caused by pests. As far as integrated pest management is concerned, it is also important to select varieties less susceptible to agrophages, as well as those adapted to the soil and climate conditions prevailing in a given oilseed rape growing area. Sowing at the optimum time and in the right amount results in stronger and more resistant to harmful factors winter oilseed rape plants.

Gradually, with the implementation of the new strategies of the European Commission, the range of active substances of plant protection products, including insecticides, is being reduced. Therefore, non-chemical methods, such as appropriate agrotechnological practices, are being intensively promoted. Although agrotechnological methods do not eliminate the threat of agrophages completely, they often contribute to limiting the threat, which in turn translates into a reduction in the level of chemicalisation (which is the main assumption of the implemented EC Strategies).

TABLE 8. Non-chemical methods of pest management of winter oilseed rape

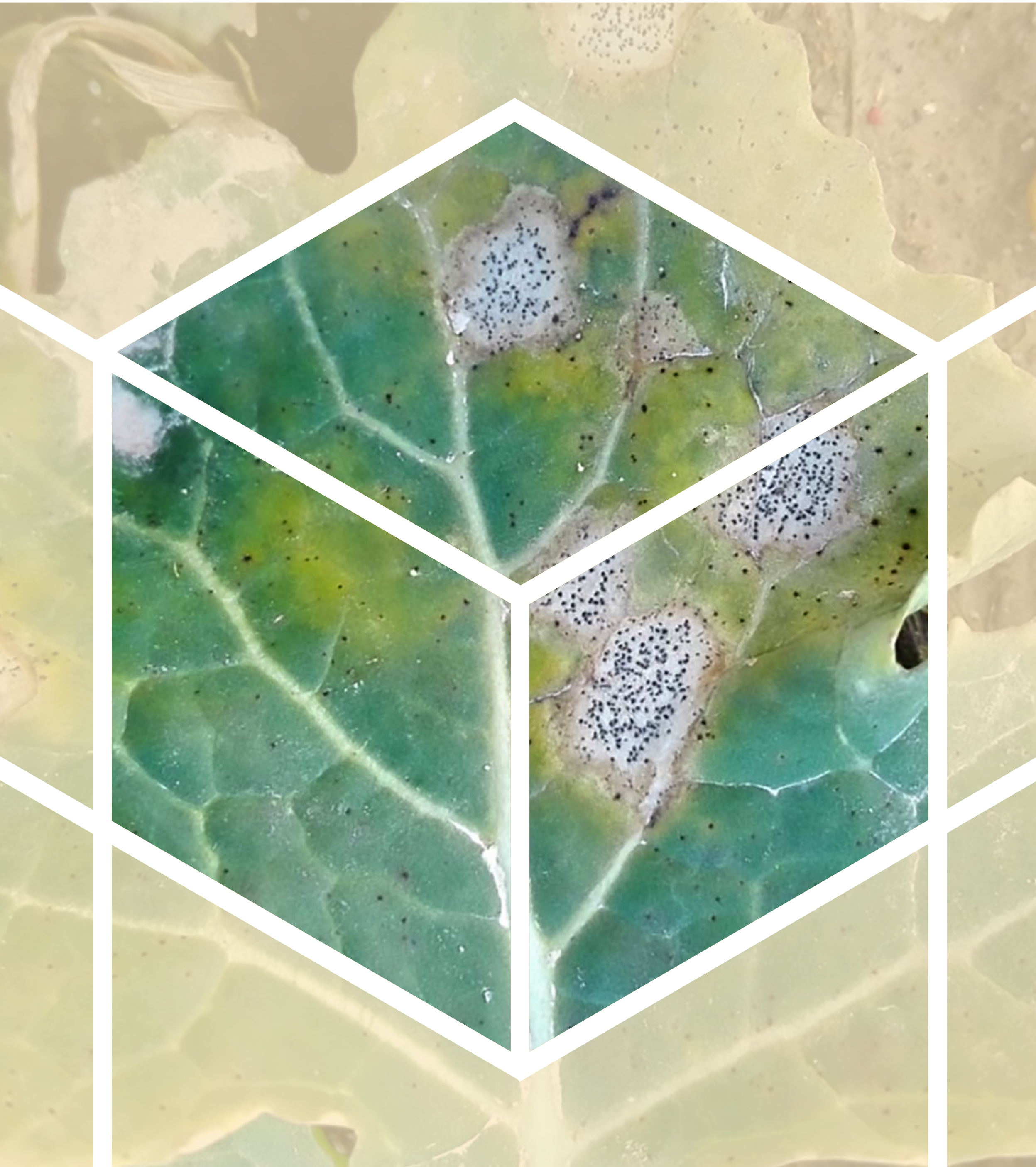
Pest	Methods and means of protection
Pieridae	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables
Ceutorhynchus napi	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables, sowing of varieties that resume growth late in the spring
Ceutorhynchus pallidactylus	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables, sowing of varieties that resume growth late in the spring
Ceutorhynchus pleurostigma	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds
Ceutorhynchus assimilis	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables, sowing of late flowering varieties
Baris	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds, increasing the sowing rate
Wireworms	appropriate cultivation practices and treatments, early sowing of seeds, increasing the sowing rate
Turnip sawfly	spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds, increasing the sowing rate
Cabbage whitefly	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables, post-harvest tillage, destruction of weeds attacking brassica plants
Cabbage leafminer	spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds, increasing the sowing rate
Cabbage aphid	spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds
Green peach aphid	spatial isolation from peach orchards and root crops, early sowing of seeds, limiting weed infestation
Nematodes	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables
Cabbage-stem flea beetle	spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds, increasing the sowing rate
Flea beetles	spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds, increasing the sowing rate
Scarabaeidae	appropriate cultivation practices and treatments, early sowing of seeds, increasing the sowing rate, spatial isolation from root crops and fallows

Table 8. Non-chemical methods of pest management of winter oilseed rape; cont.

Pest	Methods and means of protection
Brassica pod midge	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables, sowing of late flowering varieties
Black cutworm	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds, increasing the sowing rate
Common pollen beetle	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables, sowing of varieties that resume growth early in the spring, sowing of early-flowering varieties
Slugs	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds, increasing the sowing rate
Cabbage fly	spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds, increasing the sowing rate
Diamondback moth	spatial isolation from other brassica plants and brassica vegetables
Thrips	spatial isolation from other brassica plants and brassica vegetables
Rodents	appropriate cultivation practices and treatments, spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds, increasing the sowing rate
Game and birds	spatial isolation from other brassica plants and brassica vegetables, early sowing of seeds, increasing the sowing rate, using seed treatments, fencing of crops, using deterrents (physical methods)

IV

INTEGRATED PROTECTION OF WINTER OILSEED RAPE AGAINST PATHOGENS



IV.I. CURRENT AND FUTURE THREATS

Oilseed rape is cultivated in the field for more than 10 months, during which time it is exposed to the adverse effects of a number of both biotic and abiotic factors. Their appearance and severity depends on many conditions, including agrotechnological practices implemented, such as the method of cultivation and crop rotation, the variety and climatic factors, mainly temperature and humidity. Important biotic factors include pathogenic organisms. Oilseed rape is infested from sowing to harvest by many causes of disease. These include primarily fungi, but also fungus-like organisms, protozoa, bacteria, phytoplasmas and viruses. They often cause significant losses in both quantity and quality of seed yield.

Average oilseed rape yield losses due to infestation by causes of disease amount to approximately 15-20%. However, some pathogens can cause much greater losses – sometimes up to 50-70% or even 100% of potential yield. The quality of yield from plants affected by disease is also unsatisfactory, as the seeds are small, underdeveloped; smaller amounts of oil are extracted from the seeds and the oil is of inferior quality. Seeds from infested pods are often contaminated by fungi in the form of spores, mycelium or endospore forms – sclerotia. This significantly deteriorates the quality of raw material for industry and the quality of seed.

Over the years, many pathogens have either lost or gained significance; some of them became more harmful, while others do not cause as much yield loss as in the past (Table 9). It is caused by pending climate changes, which result not only in an earlier start of plant growth period and its extension in the climatic conditions of Poland, but also by frequent heat waves which result in drought and disturbance of water balance in the agricultural landscape. Climate change influences agriculture through causing intensification of biotic stresses (e.g. emergence of agrophage species new to our climate, increase of population density and extent of occurrence) and abiotic stresses (water shortage, water surplus, wrong temperature, increase of soil salinity affecting e.g. its degradation). Other reasons for differences in the significance of particular pathogenic organisms over the years include changes in approaches to agrotechnology, especially simplified tillage. Changes in the availability of plant protection products with different mechanisms of action on fungal cells are also important.In recent years, the availability of oilseed rape varieties characterized by improved resistance to one or several pathogens has increased significantly. The changing significance of existing pathogens and emergence of new disease organisms is also influenced by the inter-regional exchange of seed and agricultural equipment. Intensification of oilseed rape production results in uncontrollable multiplication of agrophages. This means that some pathogens gradually become more dangerous to oilseed rape, while others periodically do not pose a significant threat.

TABLE 9. Economic importance of causes of disease in winter oilseed rape cultivation

Disease	Cause of disease	Potential threat	
		currently	in the future
White leaf spot	*Mycosphaerella capsellae,* conidial stage *Pseudocercosporella capsella*	+	++
Alternaria brassicae	*Alternaria* spp.	++	++
Cylindrosporiosis of brassica plants	*Pyrenopeziza brassicae,* conidial stage *Cylindrosporium concentricum*	+	++
Clubroot	*Plasmodiophora brassicae*	+++	+++
Powdery mildew of oilseed rape	*Erysiphe cruciferarum*	+	+
Downy mildew of brassicae	*Hyaloperonospora parasitica, H. brassicae*	+	++
Stem canker	*Leptosphaeria maculans, L. biglobosa;* conidial stage *Phoma lingam*	+++	++
Noble rot	*Botryotinia fuckeliana;* conidial stage *Botrytis cinerea*	++	++
Verticillium wilt of oilseed rape	*Veritcillium longisporum*	++	+++
White mold	*Sclerotinia sclerotiorum*	++	+++
Damping off disease	*Pythium debaryanum, Rhizoctonia solani, Alternaria* spp.*, Phoma lingam, Fusarium* spp. and others	++	++
Oilseed rape disease caused by Phytoplasma asteris (phytoplasma disease of oilseed rape)	*Phytoplasma asteris*	+	+
Mosaic disease of oilseed rape	*Turnip mosaic virus,* TuMV	+	+
Turnip Yellow Virus	*Turnip yellow mosaic virus,* TuYV	++	+++

+ disease of local importance; ++ important disease; +++ very important disease

Depending on the growing area, the weather during the season and the developmental stage of this economically important plant, several diseases are observed, of which the causes are *Leptosphaeria maculans* (Desm.) Ces. et De Not., *Leptosphaeria biglobosa* Shoemaker et H. Brun [*Phoma lingam* (Tode) Desm.] causing stem canker, *Sclerotinia sclerotiorum* (Lib.) de Bary causing white mold, *Alternaria brassicae* (Berk.) Sacc., *A. brassicicola* (Schw.) Wiltsh. and *A. alternata* (Fr.) Keissl. – causes of *Alternaria brassicae* and *Plasmodiophora brassicae* Woronin – the cause of clubroot. Other diseases are usually of lesser importance and include damping off disease (fungal complex), noble rot [*Botryotinia fuckeliana* (de Bary) Whetzel, (*Botrytis cinerea* Pers.)], cylindrosporiosis [(*Pyrenopeziza brassicae* B. Sutton et Rawl. (*Cylindrosporium concentricum* Grev.)], white leaf spot [*Mycosphaerella capsellae* (*Pseudocercosporella capsella*)], downy mildew [*Hyaloperonospora parasitica* (Pers.) Fr.], powdery mildew [*Erysiphe cruciferarum* Opiz ex Junell]. As far as viruses are concerned, Turnip yellow mosaic virus (TuYV) is predominant and symptoms of Turnip mosaic virus (TuMV) infection are occasionally observed. Greater intensity of the latter diseases is observed in seasons and regions favourable for the occurrence of their vectors, i.e. aphids. Symptoms of infestation by *Phytoplasma asteris* can only be observed during oilseed rape ripening. Their presence is also associated with favourable conditions for increased population of insects (in autumn), vectors of this bacterium. The diseases attacking oilseed rape have one or several causes, and their importance also depends on the oilseed rape variety, i.e. winter or spring. Among the above-mentioned pathogenic organisms, a clear increase in the importance of, among others, clubroot, turnip yellow virus and verticillium wilt has been observed in recent years.

Symptoms of several diseases can be observed at a particular stages of plant development. The intensity of occurrence of diseases and potential losses they cause depend on many factors, including the population structure and biology of a given pathogen or pathogens, oilseed rape variety, cultivated varieties, climatic conditions, as well as on the applied cultivation methods, plant protection products and the dependencies between these factors.

When implementing integrated pest management methods, it is indispensable to know the sources of primary infection, i.e. the places where the pathogen lives and from which it carries out primary infection (Table 10). In the soil, on crop residues or weeds, there is a large group of pathogens in the form of endospore structures, mycelium or radicals capable of infecting new oilseed rape crops. The main source of primary infestation by *Leptosphaeria* fungi are crop residues from the previous season. Fungal endospore structures are also a major problem – they are very resistant to unfavourable effects of many environmental factors and remain viable in the soil for many years. These may be endospores of *P. brassicae* (clubroot), *Sclerotinia sclerotiorum* (causing white mold), or microsclerotia *Verticillium* spp. (verticillium wilt of oilseed rape). Seeds are also an important source of infection, especially if the seed comes from a plantation where diseases were more prevalent in the previous season.

In order to determine the threat from pests it is essential to know the approximate conditions under which the causes of disease develop most rapidly. Increased soil and air humidity as well as frequent and abundant rainfall constitute the basic conditions for quick and intense development of pathogens. Temperature plays a secondary role, however, in order for the infection to occur, certain optimal values must be maintained. In years with frequent rainfalls, diseases such as white mold, downy mildew, noble rot and clubroot pose a substantial threat whereas in dry seasons – more intensively there is verticillium wilt and powdery mildew.

TABLE 10. Most important sources of infection and diseases and favourable conditions for the development of their causes

Disease	Sources of infection	Favourable conditions for the development of disease causes	
		temperature	humidity
White leaf spot	crop residues, self-seedings, seeds	optimal: 13–18°C	high air humidity
Alternaria brassicae	seeds, crop residues, weeds	10–30°C, optimal: 20–25°C	high air humidity
Cylindrosporiosis of brassica plants	crop residues, weeds	8–24°C, optimal: 16°C	high soil moisture and air humidity
Clubroot	soil, water	6–35°C, optimal: 20–24°C	high soil moisture
Powdery mildew of oilseed rape	weeds, self-seedings	17–25°C	low air humidity
Downy mildew of brassicae	crop residues, self-seedings, seeds	8–20°C, optimal: 15°C	high (especially during germination and seedling development)
Stem canker	crop residues, self-seedings, seeds	5–25°C	high soil moisture and air humidity

TABLE 10. Most important sources of infection and diseases and favourable conditions for the development of their causes; cont.

Choroba	Źródła infekcji	Sprzyjające warunki dla rozwoju	
		temperatura	wilgotność
Noble rot	crop residues, self-seedings, weeds, seeds, soil	10–18°C, optimal: 15°C	high air humidity
Verticillium wilt of oilseed rape	crop residues, mycelium, microsclerotia in soil	16–25°C	low soil moisture
White mold	soil and seed (sclerotia)	5–25°C, optimal: 16-22°C	high soil moisture and air humidity
Damping off disease	soil, seed (sclerotia)	moderate	high soil moisture
Oilseed rape disease caused by *Phytoplasma asteris* (phytoplasma disease of oilseed rape)	other plant species	factors favouring the occurrence of vectors, mainly insects from the *Orthoptera* family	
Mosaic disease of oilseed rape	other species of brassica plants	factors favouring the occurrence of virus vectors, mainly aphids	
Turnip Yellow Virus	other arable crops (e.g. potato, beet) and brassica plants		

All parts of the plant are infected by the causes of disease, but deep infestation of root, stem and canopy tissues is the most serious for the plants. The severity of losses caused by pathogens also depends on the time of infection; the earlier the plant is infected, the greater the consequences. If the infection occurs at an advanced stage of plant development, there are usually no major yield losses. Yield reduction is associated with the fact that the assimilation processes are restricted in infected leaves, while their transpiration intensity increases. Stem infection reduces the plant's ability to transport nutrients and water, which results in wilting and dying of the plant. Pods are also infected, which often directly results in yield reduction due to seed shedding. The quality of yield from plants affected by disease is unsatisfactory, as the seeds are small, underdeveloped; smaller amounts of oil are extracted from the seeds and the oil is of inferior quality. Seeds from infested pods are often contaminated by fungi in the form of spores, mycelium or sclerotia.

Proper disease diagnosis is essential in integrated pest management. It is important to know which diseases can be observed in a given stage of plant development and the symptoms that may occur (Table 11).

TABLE 11. Diagnostic characteristics of the main diseases of oilseed rape

Disease	Diagnostic characteristics
White leaf spot	**Leaves** – irregular or oval, whitish spots with dark edges; the spots darken and become grey over time, gradually merge, and the leaves turn yellow and dry; **Stem and pods** – elongated, bright spots surrounded by a brown rim.
Alternaria brassicae	**Seedling** – narrowing of the root collar and black spots on the part of the stem underneath the cotyledon; brown, oval spots on the cotyledons; plants are weakened and die (damping off disease). **Leaves** – oval, hollow spots of light brown to black with a yellow rim, often concentric zonation on larger spots; spots gradually merge. **Stem** – longitudinal black or pale grey spots with well-defined rims on the main shoot and lateral shoots. **Pods** – longitudinal or oval, hollow brown or black spots that cause deformation of the pods and premature cracking.
Cylindrosporiosis of brassica plants	**Leaves** – concentrically arranged white spots (fruiting bodies – acervuli), which cause cracking of the epidermis, the spots are greyish-white, irregular and cause deformation and dying of the leaves. **Stem** – white or grey spots with black mottling around the rim; later on longitudinal, light brown spots with a dark rim with a rough and cracked surface. **Pods** – longitudinal, brown spots, deformation of pods.
Clubroot	**Root** – initially creamy white, hard galls of varying shape and size which then turn brown, rot and break up; galls appear on the main root and lateral roots; there are no root hairs on the root surface. **Leaves** – yellow, red or purple; wilting and hindered growth (non-specific symptoms). **Stem** – wilting and hindered growth; often accelerated budding and flowering (non-specific symptoms).
Powdery mildew of oilseed rape	**Leaves** – initially small, round clusters of mycelium in the form of a mealy white coating that gradually enlarges; leaf blades turn yellow and die. **Leaves** – initially small, round clusters of mycelium in the form of a mealy white coating that gradually enlarges; brownish-purple patches under the coating. **Pods** – initially small, round clusters of mycelium in the form of a mealy white coating that gradually enlarges.
Downy mildew of brassicae	**Cotyledons** – a fine, greyish-white coating of pathogen structures on the underside of the leaf blade; leaves turn yellow and die. **Leaves** – a fine, greyish-white coating of pathogen structures on the underside of the leaf blade; on the upper-side of the leaf blade (in the place of the coating) yellow spots with an irregular brown rim; leaves turn yellow and die.

TABLE 11. Diagnostic characteristics of the main diseases of oilseed rape; cont.

Disease	Diagnostic characteristics
Stem canker	**Seedling** – brown, oval necrosis and narrowing of the root collar or a part of the collar; plants are weakened and die (damping off disease). **Cotyledons, leaves** – oval light brown or beige necrosis often with a yellow (chlorotic) rim; clusters of pycnidia (black, spherical points) on the surface of the spots. **Stem** – longitudinal, large light brown spots with a brown rim; clusters of pycnidia on the surface of the spots. **Root collar** – initially dark brown spots that gradually begin to resemble cork and rot; stem breakage at plant maturity. **Stem** – large light brown spots with a brown rim; clusters of pycnidia on the surface of the spots.
Noble rot	**Leaves** – hollow, irregular bluish green spots, covered with a grey-brown coating of mycelium and conidial spores; leaves become deformed and die. **Stem** – hollow, irregular grey-brown spots, covered with a grey-brown coating of mycelium and conidial spores; stem breakage and death. **Pods** – hollow, irregular grey-brown spots, covered with a grey-brown coating of mycelium and conidial spores; premature drying and cracking of the pods and seed shedding.
Verticillium wilt of oilseed rape	**Leaves** – yellowing of half of the leaf. **Stem** – yellow brown, then brown streak with well-defined rims on the main shoot and lateral shoots towards the end of ripening, small, black microsclerotia of the fungus inside and on the surface of the stems; the stem epidermis cracks in strips. **Root** – dark grey, brown or black; gradually dies.
White mold	**Leaves** – brown, irregular spots on the leaves. **Stem** – whitish-grey, sometimes concentrically zoned around the perimeter of the stem; on their surface a dense, cotton wool-like white mycelium that overgrows the interior of the stem as well; black, oval fungal endospores (sclerotia) are formed within the mycelium. **Pods** – turn white; outside and inside mycelium and oval sclerotia resembling seeds.
Damping off disease	**Seedling** – oval brown necrosis on root collar and/or root; plant wilts and dies. **Cotyledons** – chlorotic or brown necrosis. **Stem** – white overgrowth of the pathogen mycelium (mildew).
Oilseed rape disease caused by *Phytoplasma asteris*	**Stem** – broom-like habit of the plant; instead of a main shoot, several stems develop; fasciation (cresting) of shoot and stem. **Flowers** – very densely set; pod-like formations grow out of the flowers (phyllodes – leaf-like forms in place of inflorescences); the plant blooms poorly and unevenly. **Pods** – very deformed.

TABLE 11. Diagnostic characteristics of the main diseases of oilseed rape; cont.

Disease	Diagnostic characteristics
Mosaic disease of oilseed rape	**Leaves** – distinct mosaic on young leaves; on older leaves the rims of the spots are blurred; leaves small and wrinkled. **Flowers** – premature falling of flower buds. Pods – deformed and less numerous.
Turnip Yellow Virus	**Leaves** – initially older leaves turn red or purple; later on symptoms also appear on younger leaves. It is often asymptomatic.

Integrated protection of oilseed rape against pathogens involves mostly implementation of agrotechnological methods, but also breeding and biological methods (Table 12). The chemical method of plant protection is allowed only when the above-mentioned methods of fighting against pathogenic organisms do not bring the desired results. However, before such methods are used, any decision should be verified by careful monitoring of the plantation and determining whether the economic damage threshold has been exceeded or by using available decision support systems (Table 13).

The grower selects the strategies to be used in integrated pest management for the purpose of reducing the occurrence and spread of diseases. Meeting the objective, i.e. effective reduction of the occurrence of diseases on plantations, requires precise knowledge of control methods and their comprehensive complementary use (Table 12). Over the years, this availability of integrated pest management methods is changing. In the case of stem canker, a common and economically important disease of oilseed rape, growers now have all of the above-mentioned methods at their disposal. In the case of other diseases, there are fewer protection methods available; sometimes the choice is limited to agrotechnological methods only.

TABLE 12. Current options for limiting individual causes of disease in oilseed rape cultivation

Disease	Method			
	agrotechnological	breeding	biological	chemical
White leaf spot	+	-	-	+/-
Alternaria brassicae	+	-	-	+
Cylindrosporiosis of brassica plants	+	-	-	+
Clubroot	+	+	-	-
Powdery mildew of oilseed rape	+	-	-	+
Downy mildew of brassicae	+	-	-	+
Stem canker	+	+	+	+
Noble rot	+	-	-	+
Verticillium wilt of oilseed rape	+	+/-	-	+/-
White mold	+	-	+	+
Damping off disease	+	-	-	+
Oilseed rape disease caused by *Phytoplasma asteris*	+	-	-	-
Mosaic disease of oilseed rape	+	-	-	-
Turnip Yellow Virus	+	+	-	-

+ – possibility to use a given method;

- – no possibility to use a given method;

+/- – possibility to use a given method in the future or on one variety of oilseed rape

TABLE 13. Economic damage thresholds and decision support systems for the main causes of oilseed rape diseases

Oilseed rape diseases	Damage thresholds (% of plants with first disease symptoms)			Examples of decision support systems
	rosette stage	start of growth period	flowering	
Cylindrosporiosis	10–20	10–15	-	-
Alternaria brassicae	20–30	10–20	10–15	-
Noble rot	20–30	10–20	10–15	-
Stem canker	10–20	10–15	-	SPEC
White mold	-	-	first symptoms of the disease (1% of plants)	Patch test

IV.2. WITHDRAWN ACTIVE SUBSTANCES

Currently, there are 19 active substances of fungicides registered for the protection of spring and winter oilseed rape – for spraying plants during growing period and for seed treatment (Table 14). European Union (EU) legislation requires active substances contained in all plant protection products to be approved by Member States for use by professional users (including growers in the Integrated Production (IP) system), who use plant protection products in their production.

TABLE 14. Current status of registration of chemical active substances of fungicides used in oilseed rape cultivation (May 28, 2021)

Active substance	Expiry date in the EU	Candidate for replacement	Number of fungicides with a given AS registered in winter oilseed rape cultivation	Number of fungicides with a given AS registered in spring oilseed rape cultivation
Azoxystrobin	31/12/2024	no	68	13
Boscalid	31/07/2021	no	11	5
Cyproconazole	31/05/2021	yes	3	2
Difenoconazole	31/12/2021	yes	34	10
Dimoxystrobin	31/01/2022	yes	2	2
Fludioxonil	31/10/2021	yes	0	3
Fluoxastrobin	31/07/2021	no	2	2
Fluopicolide	31/05/2023	yes	1	1
Fluopyram	31/01/2024	no	1	1
Flutriafol	31/05/2022	no	1	0
Isopyrazam	31/03/2023	yes	2	1
Metconazole	30/04/2022	yes	21	3
Paclobutrazol	31/05/2023	yes	10	3
Pyraclostrobin	31/01/2022	no	3	3
Prochloraz	31/12/2023	yes	20	11
Prothioconazole	31/07/2021	no	29	24
Sulphur	31/12/2022	no	0	3
Tebuconazole	31/08/2021	yes	69	20
Tetraconazole	31/12/2021	no	3	0
Thiophanate-methyl	no approval		12	7

In accordance with Regulation (EC) 1107/2009 and (EU) 2015/408, as of 2018, the European Union is withdrawing from the catalogue of available active substances those that have an adverse effect on the endocrine system of humans and warm-blooded animals. The European Commission has already withdrawn several active substances also registered for oilseed rape cultivation, namely thiram and iprodione. In accordance with the implementing European Commission regulations: EU 2020/1280, EU 2020/1498, EU 2020/2087, thiophanate-methyl, among others, was withdrawn in 2020 and can be used until 19 October 2021. The above-mentioned active substances were often an important tool used by growers to protect oilseed rape against disease causes.

More fungicide active substances may be withdrawn in the upcoming years, including several active substances in the triazole group (DMI) (Table 14). Metconazole, tebuconazole, difenoconazole, cyproconazole are very important fungicidal active substances which, if not positively assessed by the EC, will be withdrawn and there will be no possibility to use them in oilseed rape cultivation. Currently, they are ingredients of over 125 fungicides registered for the protection of oilseed rape (both as a sole ingredient or in a mixture). An important feature of – for example – metconazole or tebuconazole AS is also the possibility to regulate the habit of oilseed rape, which in autumn affects the overwintering of plants, and in spring can reduce lodging and facilitate harvest.

Insufficient availability of active substances has a negative impact not only on the economic performance of agriculture, but also deteriorates and adversely affects the environment.

In oilseed rape, this availability of active substances can be reduced by half after a negative assessment by the EC (Table 15). Among the remaining substances available to farmers, those whose mode of action is based on interference with respiration processes and inhibition of ergosterol biosynthesis will remain. Such little variation in modes of action among available AS is highly undesirable. Due to the lack of some substances, the same fungicides will be used repeatedly and sometimes more treatments will be necessary. This can lead to a reduction in the effectiveness of chemical protection, and thus a reduction in yield quantity and quality. What is the most important, with a limited number of available chemicals and their lower rotation, it is possible that pathogenic fungi become resistant to a given active substance or chemical group. The pathogenic organism becomes insensitive to the active substances used. The effect of this will be to reduce the performance of the given AS.

This situation applies primarily to the fungicide AS acting on a single target site on fungal cells, whose biosynthesis or function is determined by only one gene. It is then easy for such a gene to change, resulting in a resistant form of the fungus. Substances from chemical groups such as benzimidazoles and imidazoles, or triazoles and strobilurins of medium selectivity, commonly used in plantations, are characterised by a selective modes of action. As a result of the selection pressure exerted by the of fungicide AS used, susceptible populations of the fungus, which previously existed in the environment or have arisen as a result of variability or mutation, are gradually eliminated, while those which have not been successfully eradicated begin to develop and multiply as resistant forms. Cross-resistance can also often occur. It is based on the fact that a form of the fungus resistant to one AS is also resistant to other AS with the same mode of action. At the same time, the phenomenon of multiple resistance, consisting in the development (by some fungal strains) of resistance to two or more active substances belonging to groups of fungicides with different modes of action on fungal cells, becomes more and more common. Consequently, the fungicidal effect of such substances, applied at the recommended dose, is diminished; sometimes it is even reduced to zero.

Non-selective substances with multidirectional action disrupt many processes in fungal cells simultaneously, for example they interfere with energy processes regulated by many genes. In this case, the risk of fungal resistance is very low, but such AS are rarely used in plant protection programs.

The occurrence of fungal forms resistant to AS depends, among others, on the biology and conditions of fungal development, as well as on the intensity of plant protection. Pathogens with short growth cycles, abundant sporulation, colourless spores, rapid and distant spore dispersal are more likely to develop resistance. In practice, fungal strains resistant to fungicide AS are already identified. *Botrytis cinerea* (the cause of noble rot) and *Leptosphaeria* spp. (the cause of stem canker), for example, can quickly become resistant to the active substances used to combat them.

In order to prevent the occurrence of the resilience phenomenon, which is particularly important in the aspect of the proposed reduction of the available AS, the following rules should be observed:

- the treatment is carried out at the optimum time;
- a specific AS, in particular a selective one, with the highest possible control efficiency, is used only once per growing season;
- fungicides with active substances belonging to different chemical groups,

preferably multi-component, among which there are AS with non-selective action are used alternately;

- the product is used at the recommended rate specified in the product label;
- the susceptibility level of the fungus is permanently controlled;
- if only one fungicide is registered in a given chemical group, once its effectiveness against a given fungus species is reduced, the use of a fungicide with that active substance should be discontinued until the pathogen is found to be sensitive to it again;
- where possible, non-chemical methods are to be used in relation to limit of chemical use and thus reducing the risk of developing resistance.

It is important to know the specific chemical group into which a given active substance is classified; chemical groups define the specific modes of action to be used, can significantly contribute to delaying the selection of resistant populations and, in the case of already existing resistance, increase the probability of effective elimination of such forms. Table 15, based on FRAC (Fungicide Resistance Action Committee), has been modified to include only active substances approved for winter oilseed rape cultivation in Poland in May 2021. Individual modes of action of fungicides and possible subclasses are indicated by a letter code.

TABLE 15. Mode of action, chemical groups and active substances of fungicides recommended for winter oilseed rape

Mode of action	Group by FRAC	Chemical group	Registered active substances (28.05.2021)	Active substances to remain following a negative evaluation of the substances proposed for substitution
Blocking cell division processes	B1	Benzimidiazoles	thiophanate-methyl	-
	B5	Benzamides	fluopicolide	-
Disruption of respiratory processes	C2	Carboxamides	boscalid, fluopyram, isopyrazam	boscalid, fluopyram
	C3	Strobilurines	azoxystrobin, dimoxystrobin, fluoxastrobin, mandestrobin, pyraclostrobin	azoxystrobin, fluoxastrobin, mandestrobin, pyraclostrobin

TABLE 15. Mode of action, chemical groups and active substances of fungicides recommended for winter oilseed rape; cont.

Mode of action	Group by FRAC	Chemical group	Registered active substances (28.05.2021)	Active substances to remain following a negative evaluation of the substances proposed for substitution
Interference with signal transduction through membranes	E2	Phenylpyrroles	fludioxonil	-
Inhibition of ergosterol biosynthesis	G1	Imidazoles	prochloraz	-
	G1	Triazoles	cyproconazole, difenoconazole, flutriafol, metconazole, prothioconazole, tebuconazole, tetraconazole	flutriafol, prothioconazole, tetraconazole
Effects on multiple components of the pathogen's metabolism	M	Inorganic	sulphur	sulphur

IV.3. SUBSTITUTES FOR WITHDRAWN ACTIVE SUBSTANCES

In winter oilseed rape (as of May 2021), 233 fungicides for spraying during growing season and 2 seed treatments are registered, while in case of spring oilseed rape, 79 fungicides and 5 seed treatments will be registered, after deletion of the proposed active substances, this number will be significantly reduced (Table 14 and 15). This availability of these products will be cut by more than a half. In case of some disease causes, it will no longer be possible to control them with plant protection products (Table 16). This includes the control over clubroot, which is an economically important disease. In some cases it is possible to extend the registration of fungicides, the active substances of which are not candidates for substitution (if all conditions are met) (Table 16). However, in many cases the withdrawn active substances cannot be replaced to their full extent. The only hope is that new active substances with a safe ecotoxicological profile will be approved. The withdrawn active substances will be replaced by active substances from the group of carboxamides (SDHI). However, the latest generation of fungicides are often more expensive compared to the withdrawn products, which will increase crop production costs. In the case of white mold and stem canker, biofungicides can support measures to control the causes of these diseases. There are currently 4 registered plant protection products, the active substances of which are microorganisms (Table 16).

Protection of oilseed rape against pathogenic organisms will therefore require introduction of non-chemical methods of reducing pathogen populations. This is in line with the principles of integrated pest management that are being implemented since 2014.

The most important elements in this case will be the use of appropriate agrotechnology, availability of biofungicides and varieties resistant and tolerant to agrophages.

TABLE 16. Comparison of protection options for winter oilseed rape – currently and after the upcoming introduction of changes proposed by the EC

Disease	Examples of active substances and their mixtures registered for the control of causes of oilseed rape diseases – as on May 2021	Examples of active substances and their mixtures for the protection of oilseed rape to remain following the negative assessment of the proposed substitutes
Cylindrosporiosis	difenoconazole; metconazole; tebuconazole; difenoconazole + paclobutrazol; difenoconazole + tebuconazole	prothioconazole (not registered)
Alternaria brassicae	azoxystrobin; boscalid; difenoconazole; flutriafol; metconazole; prochloraz; prothioconazole; tebuconazole; thiophanate-methyl*; prothioconazole + tebuconazole; prothioconazole + fluopyram; difenoconazole + paclobutrazol; tebuconazole + difenoconazole; thiophanate-methyl* + tetraconazole; prochloraz + tebuconazole; dimoxystrobin + boscalid; pyraclostrobin + boscalid; metconazole + boscalid; azoxystrobin + cyproconazole; fluopicolide + fluoxastrobin;	azoxystrobin; boscalid; pyraclostrobin + boscalid; flutriafol; prothioconazole; prothioconazole + fluopyram;
Clubroot	thiophanate-methyl*	-
Powdery mildew	difenoconazole; tebuconazole; difenoconazole + tebuconazole; thiophanate-methyl* + tetraconazole; sulphur (spring oilseed rape only)	sulphur
Downy mildew	fluopicolide + fluoxastrobin; prothioconazole + tebuconazole; pyraclostrobin + boscalid;	pyraclostrobin + boscalid;

TABLE 16. Comparison of protection options for winter oilseed rape – currently and after the upcoming introduction of changes proposed by the EC; cont.

Disease	Examples of active substances and their mixtures registered for the control of causes of oilseed rape diseases – as on May 2021	Examples of active substances and their mixtures for the protection of oilseed rape to remain following the negative assessment of the proposed substitutes
Stem canker	azoxystrobin; boscalid; difenoconazole; metconazole; prothioconazole; thiophanate-methyl*; tebuconazole; prothioconazole + tebuconazole; difenoconazole + paclobutrazol; difenoconazole + tebuconazole; prochloraz + tebuconazole; dimoxystrobin + boscalid; thiophanate-methyl* + terconazole; pyraclostrobin + boscalid; difenoconazole + azoxystrobin; fluopicloide + fluoxastrobin; *Pythium oligandrum; Bacillus amyloliquefaciens* strain MBI600	azoxystrobin; boscalid; pyraclostrobin + boscalid; prothioconazole; *Pythium oligandrum; Bacillus amyloliquefaciens* strain MBI600
Noble rot	azoxystrobin; boscalid; flutriafol; metconazole; prochloraz; tebuconazole; thiophanate-methyl*; prothioconazole + tebuconazole; difenoconazole + paclobutrazol; thiophanate-methyl* + tetraconazole; prochloraz + tebuconazole; dimoxystrobin + boscalid; pyraclostrobin + boscalid; prothioconazole + fluopyram; metconazole + boscalid; azoxystrobin + cyproconazole; azoxystrobin + tebuconazole + difenoconazole	azoxystrobin; boscalid; pyraclostrobin + boscalid; flutriafol; prothioconazole + fluopyram
Verticillium wilt	azoxystrobin (spring oilseed rape only)	azoxystrobin
White mold	azoxystrobin; boscalid; difenoconazole; flutriafol; prochloraz; prothioconazole; tebuconazole; thiophanate-methyl*; prothioconazole + tebuconazole; difenoconazole + paclobutrazol; difenoconazole + tebuconazole; prochloraz + tebuconazole; dimoxystrobin + boscalid; pyraclostrobin + boscalid; thiophanate-methyl* + tetraconazole; azoxystrobin + isopyrazam; difenoconazole + azoxystrobin; prochloraz + tebuconazole; azoxystrobin + boscalid; metconazole + boscalid; prothioconazole + fluopyram; azoxystrobin + difenoconazole; azoxystrobin + tebuconazole; fluoxastrobin + tebuconazole; azoxystrobin + cyproconazole; azoxystrobin + tebuconazole + difenoconazole; *Coniothyrium minitans; Pythium oligandrum; Bacillus subtilis* strain QST 713	azoxystrobin; boscalid; flutriafol; prothioconazole; pyraclostrobin + boscalid; prothioconazole + fluopyram; azoxystrobin + boscalid; *Coniothyrium minitans; Pythium oligandrum; Bacillus subtilis* strain QST 713
Damping off disease	fluopicoloide + fluoxastrobin; fludioxonil (spring oilseed rape only)	-

*Products containing thiophanate-methyl may be used until 19 October 2021.

IV.4. SCOPE FOR USING BIOLOGICAL METHODS

For biological protection of oilseed rape against disease causes, 4 biological fungicides based on the *C. minitans hyperparasite, P. oligandrum* parasite and the *B. amyloliquefaciens* and *B. subtilis* bacteria were registered (Table 17). In the case of biological agents, as in the case of chemical agents, for the control of disease perpetrators, the timeliness of treatments is one of the key conditions for ensuring their effectiveness.

There are many disease causes that are only controlled at certain stages of development and failure to treat or a prolonged delay in treatment may not be effective.

TABLE 17. List of registered biofungicides in oilseed rape (May 2021)

Disease	Biofungicide name	Active substance (microorganism)	Dose
White mold	Constans WG	Fungus – *Coniothyrium minitans* strain CON/M/91-08	2 kg/ha
	Polygreen Fungicide WP	Oospores – *Pythium oligandrum* M1	0.1 kg/ha
	Serenade ASO	Bacterium – *Bacillus subtilis* strain QST 713	2 l/ha
Stem canker	Integral Pro	Bacterium – *Bacillus amyloliquefaciens* strain MBI600;	160 ml/100 kg of seed; 12.8 l/ha
	Polygreen Fungicide WP	Oospores – *Pythium oligandrum* M1	0.1 kg/ha

The *C. minitans* fungus controls the causes of white mold and can serve as a preventive measure, therefore it is recommended to apply the product before sowing winter oilseed rape; the does should be 2 kg/ha. After spraying, the soil should be mixed to a depth of about 5–10 cm. In this way it is possible to destroy the source of the infection by pathogens, which is found in the soil, crop residues, self-seeds, weeds and seeds. The *C. minitans* fungus causes lysis, i.e. dissolution of cell walls and degradation of sclerotia (a type of spores), inhibits the pathogen's sapling growth and metabolic processes. The spores of the fungus germinate in moist soil, forming a mycelium that penetrates the spores of the colonized fungus.

Enzymes dissolve the cytoplasmic walls of the host. The hyperparasite uses the host's organic components as a source of nutrients for its growth. At the same time, the fungus has the ability to degrade oxalic acid that is toxic to plants and is produced by the *S. sclerotiorum* during tissue colonization. It also secretes macrolides that inhibit the pathogen's mycelium, which limits its ability to infect plants. *C. minitans* is extremely selective and attacks only the sclerotia of the pathogen. The fungus recognizes chemical signals from the host and searches for it in the soil. In soil, it acts during plant development and also reduces the risk to succeeding crops and crops of the same species in subsequent years. The fungus persists in the soil in subsequent years and exhibits crop protection effects. *C. minitans* spores can survive without germinating in damaged sclerotia for at least a year. There is data that the fungus can be found in the soil at least 18 months after application.

Unlike chemical fungicides, *C. minitans* has a long-lasting effect, eliminating the pathogen's sclerotia and mycelium from the soil and from harvested crops during storage. When applied to soil, it supports plant cultivation, improves their development and condition, and thus increases yield. Studies conducted in Poland indicate that under favourable conditions *C. minitans* can infect 85–99% of pathogen sclerotia.

Dozens of fungicides are registered for white mold control during flowering. The effect of these measures may be supported by a biological product applied to the soil before sowing oilseed rape. However, biological protection will be about 20-30% more expensive than chemical protection. Therefore, the introduction of subsidies for the use of biological protection will encourage producers to change their approach to protection and move towards integrated protection which reduces the use of chemical plant protection products.

Studies in the Netherlands and Belgium show that the highest efficiency of preparations based on *C. minitans* is achieved with a surface application. Chemical fungicides that protect plants from noble rot and white mold must not be applied to the soil at this time. It must not be mixed with other chemical fungicides, acids or alkaline products and all products that may react with organic matter. The product is also recommended for use in organic crops. The use of biofungicide does not require a withdrawal period, has no toxic effect on other organisms, and has no phytotoxic effect on crops.

A Serenade ASO biofungicide has been recently registered for the protection of oilseed rape against white mold, the active substance of which is *Bacillus subtilis*

QST 713 strain. The action of the bacteria is to disrupt mycelial growth by contact with the pathogen on the plant surface and to produce substances that interfere with the function of the fungal cell membranes. *B. subtilis* also competes with pathogens for living space and nutrients and induces systemic plant resistance. In oilseed rape, this product is applied preventively, from the beginning to the end of the flowering stage (BBCH 60–69). The recommended dose is 2 l/ha, the maximum number of treatments in the growing season – 2, the interval between treatments is at least 5 days, the recommended amount of water: 100-400 l/ha Recommended spraying: fine droplet spray.

The parasitic organism *P. oligandrum* protects the root zone from fungal diseases. It decomposes fungal fractions causing white mold and stem canker, stimulating the immunity mechanisms of oilseed rape. This fungus is naturally occurring in the soil environment and has a broad spectrum of activity. It secretes oligandrin, a protein belonging to the group of elicitins that have the ability to induce systemic resistance in plants. *P. oligandrum* introduces phytohormones as well as phosphorus and sugars to the plant. The fungus inhabits the root zone of plants. For better plant coverage, you can add a wetting agent to the preparation. The best effect is obtained on soils with pH 5.5–7.5 and soil temperature of 12–25°C. Spraying treatments are best carried out in the morning or evening, strong sunlight should be avoided due to the negative effect on the spores of the fungus.

White mold can be treated during different periods, depending on the situation on the plantation:

a) – the first treatment should be carried out in autumn at the stage from 2 to 9 leaves (BBCH 12–19),
   – the second treatment should be carried out in spring at the stage of growth (elongation) of the main shoot (BBCH 30–40).

or:

b) – the first treatment should be carried out in spring at the stage of growth (elongation) of the main shoot (BBCH 30–40).
   – the second treatment should be carried out at the stage from 9 or more internodes to full flowering (BBCH 40–65).

Number of treatments: 2. Interval between treatments: at least 14 days.

When treating stem canker, three treatments should be made depending on the situation in the field:

a) – the first treatment should be carried out in autumn at the stage from 2 to 9 leaves (BBCH 12–19),
   – the second treatment should be carried out in the spring at the rosette stage (BBCH 30–40),
   – the third treatment should be carried out at the stage from 9 or more internodes to full flowering (BBCH 40–65).

or two treatments:

b) – the first treatment in the spring at the rosette stage (BBCH 30–40),
   – the second treatment should be carried out at the stage from 9 or more internodes to full flowering (BBCH 40–65).

Number of treatments: 2–3. Interval between treatments: at least 14 days.
Recommended amount of water: 300–400 l/ha, preferably with a fine droplet spray.
The maximum number of treatments per growing season is 3.

P. oligandrum has a broad spectrum of activity. Reduces the occurrence of such plant pathogens as: *Pythium* spp., *Rhizoctonia* sp., *Phytophthora* sp., *Phoma* sp., *Verticillum* sp., *Sclerotinia* sp. and *Fusarium* sp., i.e. the causes of damping off disease, fusariosis, noble rot, and others.

The fungus-like organism *P. oligandrum* may also reduce to some extent the occurrence of the sources of clubroot (*Plasmodiophora brassicae*). It can be supported by a treatment done in early autumn – after two leaves have appeared – then repeated in spring after the beginning of the growing period. Moreover, the biopreparation is harmless to bees and is not phytotoxic. However, its effectiveness requires adapting a suitable approach, so it is necessary to maintain appropriate air and water conditions in the surroundings of the root system. Mistakes made within the field of irrigation lead to a reduction in its effectiveness.

Chemical treatments (dressings) can be replaced by the *B. amyloliquefaciens* bacterium. It is used for the purpose of protecting winter oilseed rape against stem canker. It is at the time of emergence, in the stage of fully developed cotyledons and the first foliage, that the first symptoms of stem canker and *Alternaria brassicae* can be observed on plants. At this stage, problems should be solved by seed treatment. *B. amyloliquefaciens* also acts as a stimulant of natural plant defence mechanisms, thus reducing damage. The agent containing the bacterium may have variable levels of action and therefore satisfactory efficiency cannot be expected in all cases. The recommended dose is 160 ml per 100 kg of seed (12.8 ml/ha). Recommended amount of water: 10–20 ml for each ml of the agent.

It is also applied to the soil or sprayed with a bacterial soil preparation based on *Bacillus subtilis* bacteria. A product called Bi Protect is not registered as a biofungicide, but it is a common knowledge that it can reduce clubroot. The *B. subtilis* bacterium is common in soil in our climatic zone. It is a saprophyte, decomposing organic compounds of plant origin. Reduces pathogenic fungi and bacteria in the soil contributing to the improvement of the phytosanitary status of crops. The bacterium improves soil properties and accelerates the decomposition of organic matter. It is characterized by a high rate of growth in the soil. There are also known cases of reduction of nematode populations (plant parasites) by this bacterial species. The positive effects of bacteria in soil are:

- co-formation of the lumpy structure of the soil,
- formation of soil colloids and slime layer,
- beneficial effect on plant health and improvement of yield size and quality,
- reduction of pathogens,
- support of the development of beneficial soil bacteria,
- help in breaking down organic matter,
- ability to bind iron ions by combining all available forms of iron into chelates (complex compounds) and making them available to plants,
- increase of moisture within the root system.

The product is applied in spring before sowing or in autumn on crop residues at a dose of 0.5–1 Kg/ 200–350 l of water/ha, 1–2 times a season (in spring before sowing or on the plantation and in autumn on crop residues).

In field crops, the use of biopreparations containing parasitic microorganisms is not common. First of all, the interest of producers in these measures is quite insignificant, because their effectiveness is often much lower than after the application of chemical plant protection products. Their effectiveness is affected by weather conditions in the field, which change frequently. Those include: temperature, humidity and sunshine. However, it is important to remember that introducing these agents into the environment retains them for a long period of time. Under favourable conditions, they are effective for many years and, without human intervention, can result in the reduction of many causes of plant diseases.

IV.5. RESISTANT AND TOLERANT VARIETIES

Variety is recognized as one of the main determinants of crop production growth in modern agriculture. Varietal progress is achieved through intentional genetic changes aiming at improving specific agricultural and performance characteristics of varieties. It is most often associated with yield increase, but it also includes many other traits that determine the economic value of a variety. In particular, this is applicable to the quality of the yield and the resistance or tolerance to various biotic factors (diseases, pests) and abiotic factors (high and low temperatures, excess and deficiency of rainfall, soil quality, etc.) that reduce yield, as well as other specific characteristics that determine the agricultural or performance characteristics of the varieties. The ability to recover quickly from stress is also a desirable property of the new varieties. This is important in the view of a changing climate and increasingly frequent extreme weather events that significantly affect plant growth period.

The varieties improved as a result of breeding work are an answer to the requirements set mainly to rationalize (reduce) the level of mineral fertilization, in accordance with the *Regulation of the Council of Ministers* of June 5, 2018 on the adoption of the "Programme of measures to reduce water pollution by nitrates from agricultural sources and to prevent further pollution" (Journal of Laws of 2018, item 1339) and to reduce the number of plant protection treatments to best meet the expectations of integrated systems of plant protection and production. Such varieties – characterized by high yielding potential and very good health manifested in resistance to various pathogens – will constitute an important factor allowing to meet the assumptions of the EU *Farm to Fork* Strategy, which is an element of the European Green Deal, which assumes, among others, a radical reduction of the use of chemical plant protection products and fertilizers.

Cultivation of varieties resistant or tolerant to harmful organisms is one of the basic principles of integrated crop protection, including of oilseed rape. In sustainable agriculture, resistant varieties represent a specific and ecological means of production. Therefore, breeding of resistant varieties is essential for popularising integrated pest management and production. It is estimated that the average yield loss of oilseed rape due to various causes of disease is about 15–20%, which has a significant economic impact. However, in the case of some pathotypes, e.g. clubroot, the yield potential losses may be much higher; in extreme cases the plantation of infected plants must be destroyed.

Breeding of varieties resistant to pest organisms is not easy. It requires detailed recognition of the interrelationships between the plant/host, the pathogen and the environment, as well as a thorough understanding of the biology of pathogen development. It is also necessary to identify resistance genes, often in related plants, and then establish how to genetically determine such resistance. In order to achieve this, breeders use modern biotechnological methods and molecular biology in their research, which enable continuous progress of breeding work. Breeding of resistant varieties will be even more effective when various new sources of resistance are found and then transferred to crop varieties for use in production.

Taking into account the different aspects of varieties breeding mentioned above, it should be emphasized that breeding a new variety is a complex process and usually takes many years (7-8 years on average). Therefore, new varieties meeting the expectations of users applying integrated cultivation and protection of oilseed rape will become available gradually, over many years. In order to be effective, modern, creative breeding should have stable sources of financing, necessary for achieving the objectives set.

Implementation and promotion the principles of integrated pest management will force the breeding companies to intensify their work aimed at breeding varieties resistant to various stress factors, especially pathogens. On the other hand, it will increase the interest in varieties resistant to natural yield-limiting factors. In addition to varieties resistant to various pathogens, varieties tolerant to different stresses can play an important role in plant protection systems. Varieties characterized by their ability to recover from various damages and return to further growth and development after being subjected to severe stress will also be more valuable. The widespread use of integrated pest management will therefore require comprehensive recognition of the properties of the varieties tested, especially a detailed assessment of their field resistance to stress factors, including diseases.

Plant disease resistance is a genetically determined property. There are basically two main types of disease resistance: race-specific resistance, also called monogenic or vertical resistance, and race-nonspecific resistance, also called polygenic, partial or horizontal resistance. The former is determined by single genes and is a fairly effective temporary protection against disease infection. Over time, however, it breaks down under field conditions, usually under high pressure from a pathogen whose infectivity also changes as a result of transformations that occur in the whole population. The second is conditioned by multiple host plant genes and show small unit effects. Its effectiveness is quite variable, but it is more long-lasting and does not break down in varieties grown in production fields. Currently, in breeding work, the most effective way to create disease resistant varieties is to combine race-specific and polygenic resistance in the genotype.

Disease tolerance as well as resistance to other stresses caused by non-living factors may also play an important role in the proposed plant protection systems. Tolerance refers to the genetically and environmentally determined ability of plants of certain varieties to withstand infestation by diseases or other harmful organisms or to environmental stresses. Stress-tolerant varieties withstand stress factors without major yield losses. Under field conditions, the degree of infestation of e.g. disease-tolerant varieties is visually similar to that of susceptible varieties, but the negative effect of the disease agent is different.

Among oilseed plants, due to the economic importance and the large extent of cultivated area, the most intensified breeding work for creating new and better varieties is conducted in winter oilseed rape. In this species, breeding progress in terms of seed yield size and quality, as well as resistance traits, is relatively high. Creative breeding work is conducted in a dozen or so foreign breeding and seed companies, supported by various scientific institutes, as well as in two domestic plant breeding companies, operating within the structure of the Plant Breeding and Acclimatisation Institute – National Research Institute.

New varieties developed by breeders are submitted for official testing for entry into the Polish National List of Agricultural Plant Varieties. Official examinations of the economic value and distinctness, uniformity and stability (DUS) of the varieties are carried out by the Polish Official Variety Testing (COBORU). After a 2- to 3-year study period, about 15 (out of nearly 100 reported) of the most valuable varieties are registered each year.

The basic criteria for determining the economic value of a variety include:

- quantity of the yield.
- stability of yields throughout the years and in different regions
- yield quality (e.g. fat, glucosinolates, protein and fibre content of the seed)
- resistance and tolerance to disease
- response to stress conditions (low temperature, drought, hail and others)
- resistance to lodging
- the ability to adapt to various growing conditions.

In the process of registration testing of new varieties, field resistance to pathogens is evaluated in rigorous experiments. Resistance of varieties to pathogens and stress conditions (e.g. frost, drought), apart from seed yield and their quality, constitutes one of the main criteria in making a decision on entering a variety into the Polish National List of Agricultural Plant Varieties. Unfortunately, resistance of varieties to individual causes of disease is not complete. However, in case of such varieties, the infection has a much milder course. Mostly varieties are resistant to only one pathogen, however, more and more recent varieties are resistant to two or more causes of disease.

A variety entered into the Polish National List of Agricultural Plant Varieties is propagated and its seeds are offered for sale and then cultivated. Due to the constant creation of many new varieties by breeders, older varieties are quite quickly replaced on the market and in cultivation. The average period of availability of the variety in the commercial offer is approximately 5-7 years.

At present, over 150 winter rape varieties are listed in the Polish National List of Agricultural Plant Varieties. Three quarters of these are hybrid varieties. Nearly ninety percent of the varieties entered in the Polish National List come from abroad. Nearly three quarters of the registered varieties are new varieties, entered into the list in the last seven years. The large share of new varieties in Polish National List allows for relatively fast introduction of breeding progress into production (Table 18).

TABLE 18. Status of The Polish National List of Agricultural Plant Varieties (NL) of winter oilseed rape in 2015–2021

Specification	2021	2020	2019	2018	2017	2016	2015
Number of varieties entered into the Polish National List of Agricultural Plant Varieties	155	161	153	140	128	121	111
• hybrid varieties	121	124	114	102	90	80	72
• open-pollinated variety	34	37	39	38	38	41	39
Number of varieties registered in the year	16	16	17	18	14	20	14
• hybrid varieties	15	13	15	15	14	12	14
• open-pollinated variety	1	3	2	3	0	8	0
Number of breeding companies which produced varieties that were entered into the Polish National List in the year	10	7	9	7	9	10	5

Cultivation of new varieties by oilseed rape growers makes it possible to benefit from the biological progress that these varieties bring. It is manifested mainly in a very high yielding potential, while most of the new varieties are characterized by generally good health, but also increased resistance to certain pathogens, such as stem canker or turnip yellows virus.

In order to benefit from biological progress, it is essential to sow certified seed of particular varieties. Due to the fact that the production and evaluation of such seed is subject to official control, only seeds that have the required quality parameters and are properly prepared (i.e. usually treated with a well-chosen and approved seed treatment as well as packed and stored in a way that guarantees preservation of its properties) are launched on the market.

Only such seeds ensure varietal identity, i.e. manifestation of features, both morphological and functional, characteristic for a given variety, including e.g. resistance to specific pathogens. Certified seed should also guarantee an adequate seed value. In addition, certified seeds should not contain more than 1% erucic acid and no more than 15 μM glucosinolates per g of seed. The use of other than certified seed results in a significant reduction in seed yield and deterioration of its quality.

For many years now, seed distributors have been selling seed in the form of the so-called seed units. Such a unit should contain a certain number of seeds germinating on an assumed fixed area. The area of 3 ha is usually assumed, for which 2.0–2.1

million seeds of open-pollinated varieties or 1.5 million seeds of hybrid varieties are expected to be sown. The packaging contains the necessary information (crop, variety name, seed value parameters, number of seeds, sowing area, etc.). Usually, seed of new varieties or varieties that have additional properties such as resistance to specific pathogens are expensive.

In recent years, differences in variety seed prices can be ascribed to the available seed treatments. Still, it is a good idea to obtain good, albeit expensive seeds. On average, their price represents only about 5–7% of the total cost of oilseed rape cultivation. It is worth knowing that basic or certified oilseed rape seed used for sowing are not covered by *de minimis* aid.

The greatest progress is observed in the breeding of hybrid varieties, which are created as a result of controlled cross-pollination of appropriately selected initial pure breeding lines.

To obtain a fully hybrid F1 generation, cytoplasmic-genetic male sterility systems are used in breeding. F1 varieties are mainly characterized by a higher yield potential, but often also more vigorous plants and faster development. Taking into account individual years in which the study was conducted, in PDO experiments these varieties had a yield higher by several percent (10-16% on average) compared to open-pollinated varieties. (Table 19). The seed of hybrid varieties are F1 seeds, produced through crossing fixed breeding lines and/or varieties, according to a hybrid formula known only to the breeder. In hybrid varieties, higher yield occurs only in the F1 generation and is not repeated in subsequent propagations. Therefore, production plantations should be sown with certified seed.

Hybrid varieties also enhance the progress in breeding of resistant varieties, in which synthetic breeding lines are created for the introduction of genes determining resistance e.g. to causes of clubroot, turnip yellows virus or stem canker. In recent years, the share of hybrid varieties grown in our country has also increased considerably. They are more available as a significant number of such varieties has been launched on the market and the seeds can be easily purchased.

TABLE 19. Seed yield of winter oilseed rape varieties tested in PDO tests in 2015–2020

Specification		Average	Seed yield [dt/ha]					
			2020	2019	2018	2017	2016	2015
All varieties tested		**42.4**	46.6	38.5	37.6	44.2	39.1	48.5
Hybrid varieties		**43.5**	47.5	39.3	38.7	45.5	40.0	49.7
Open-pollinated varieties		**38.5**	41.7	34.8	33.4	40.2	35.6	45.0
Difference	[dt/ha]	**5.0**	5.8	4.5	5.3	5.3	4.4	4.7
	[%]	**13.1**	13.9	12.9	15.9	13.2	12.3	10.4

High-yielding varieties with reduced soil requirements are particularly valuable, which makes it possible to grow them on sites where the conditions for cultivation are not the best. Such varieties, characterized by a better use of nitrogen in the soil, are already bred by some foreign breeding and seed companies. During growing season, in which adverse climatic events occurred more intensively, hybrid varieties usually responded with a smaller decrease in yield. Most of these varieties tolerate later sowing thanks to faster initial development. The plants develop a stronger, more extensive root system, which makes it easier for them to absorb water and nutrients.

Hybrid varieties constitute the main breeding progress in oilseed rape cultivation:

- many of them contain additional genes responsible for resistance to pathogens, e.g. *Rlm9, Rlm7, Rlm3, RlmS* (*Apr37*) (stem canker), TuYV (turnip yellow virus),
- varieties resistant to clubroot disease are being developed,
- varieties with increased resistance to pod cracking and seed shedding are available,
- varieties tolerant to the active substance (imazamox) from the imidazoline group, used in herbicides to control many weeds as well as brassicas (the so-called Clearfied cultivation technology), are also being bred,
- semi-dwarf varieties are also available on the market.

It should also be taken into account that in our country, there are still many growers who accurately assess the suitability of open-pollinated varieties for their farming conditions and often cultivate them in their fields. Such varieties are mostly sown on smaller farms, on limited areas and sites characterised by slightly worse conditions for cultivation. Their main advantage is that they are relatively easy to harvest due to the lower plant weight. Some of the open-pollinated varieties are also less affected by particular diseases or more tolerant to adverse weather conditions. Unfortunately, open-pollinated varieties will become less and less available in the upcoming years; thus, these varieties will be less competitive with hybrid varieties. Seed of open-pollinated varieties is cheaper.

The type of cultivated variety is one of the main factors determining the increase in production and proper quality of obtained oilseed rape seeds. High and stable yielding under various soil and climatic conditions, as well as in consecutive growing season (which usually differ as far as rainfall and thermal conditions are concerned), determines the value of the variety. Oilseed rape growers should know that in addition to the right choice of variety that would be adapted to specific farm conditions, they must implement appropriate agrotechnological practices. Concurrent use of appropriate varieties as well as agrotechnological practices allows for better use of the yield-forming potential of the cultivated plants. In the last six years, an average 68% of the yield obtained in field experiments came from production, while the variation in this relation in individual years ranged from 59% to 74%. This indicates the possibility of greater use of the yield-forming potential of varieties by oilseed rape growers (Table 20).

TABLE 20. Cultivated area and average seed yield of winter oilseed rape in PDO tests and in production in 2015-2020 (data collected by GUS and COBORU)

Year	Cultivated area (in thous. ha)	Seed yield (dt per ha)		Relation b/a (in %)
		PDO	Production	
		a	b	
2020	881.4	46.6	31.5	68
2019	848.0	38.5	27.9	72
2018	812.7	37.6	26.1	69
2017	879.1	44.1	29.7	67
2016	738.0*	36.6	27.0	74
2015	884.2	48.5	28.5	59

* reduced cultivated area due to frost damage and the destruction of part of the crop.

Note: Cultivation area and seed yield (production) – data obtained from GUS and ARiMR

The ongoing progress in breeding and creation of more and more specialized varieties makes it necessary to use complex and precise agrotechnology adapted to the requirements of individual varieties. Oilseed rape cultivation is quite demanding in terms of expenditure, required time and precision of agrotechnological operations (especially sowing), plant protection and seed harvesting. The agrotechnological factor is particularly important in the view of the escalating problems resulting from the large area of winter oilseed rape cultivation, such as self-seeding, compensation of some weeds, or more frequent occurrence of many diseases and pests, e.g. clubroot, weevils.

The occurrence of a specific disease in an oilseed rape plantation depends on many factors. These include natural factors which do not depend on the farmer's/producer's actions and those which they decides on, such as the agrotechnology used. Natural factors, in addition to the quality and moisture of the soil, especially the amount and distribution of rainfall during the growing season, the temperature sum and sunshine. The probability of the occurrence of diseases is higher when oilseed rape is grown on the same field too often, simplified cultivation is used, sowing is too deep or too compacted, and the plantation is infested with weeds.

In addition, poorly nourished plants are more susceptible to disease infections. Increased damage by pests always results in a higher infestation with pathogens. This is due to the fact that the damage is a "gateway" for spores, including stem canker, white mold, cylindrosporiosis and noble rot.

Carefully selected varieties will be an important element of integrated oilseed rape cultivation and protection. In order to make integrated protection more popular, it will be necessary to conduct such experiments that will allow for a more precise assessment of the resistance of varieties to the most important pathogens, as well as for a better definition of their agrotechnological requirements. It can be assumed that with good recognition of the frequency of occurrence of a given phenomenon and knowledge of the most important characteristics of varieties, it should be possible to better adapt the cultivation technology to specific varieties and thus improve the profitability of production. This is applicable in particular to the number of plant protection treatments, their timing and the appropriate dosage. It will be reasonable to limit the use of or refrain from using a fungicide when the cultivated variety is resistant to the pathogen in question. On the other hand, for varieties with lower resistance it will be advisable to apply a higher dose, or even to perform more treatments. However, integrated pest management should always take into account the principles of good agricultural practices and prioritise implementation of agrotechnological measures over the use of plant protection products.

A prerequisite for the positive use of resistance traits in sustainable cultivation is first and foremost a sufficiently large diversity of varieties. If all of the available varieties are resistant to the same pathogens, even the most important traits cease to be of practical importance and may be overlooked when selecting a variety. With a large number of varieties, defining appropriate evaluation criteria and preferences is crucial in selecting the right variety. However, there is always some risk of selecting a wrong variety, despite access to up-to-date results of variety tests. In order to at least partially prevent such situations, more than one variety should be grown on a farm, especially on large areas of land. After considering the basic criteria (yield, quality), it is good to ensure that varieties are favourably rated or differ in other important agricultural traits, including disease resistance.

Observations pertaining to the level of infestation of varieties by causes of disease, resulting from testing conducted within the framework of Post-Registration Variety Testing System (PDO) indicate that in our country winter oilseed rape plants are most often attacked by pathogens causing white mold, Alternaria brassicae and stem base diseases, including in particular stem canker (Table 21). In a small number of tests, infestation of plants by organisms causing powdery mildew and noble rot was observed. The frequency of occurrence of the above-mentioned diseases depends to a large extent on the intensity of oilseed rape cultivation in the region in question. A large share in the sowing structure and too frequent succession of crops in the same field are conducive to the spread of, in particular, stem canker and other diseases of the stem base, and recently also verticillium wilt. Infection of oilseed rape plants with turnip yellow virus (TuYV) has also been a major problem in recent years.

TABLE 21. Frequency of selected diseases of winter oilseed rape in PDO tests in 2015–2020 (% of tests in which plant infection by pathogens occurred)

Disease name	Average	Growing season					
		2020	2019	2018	2017	2016	2015
White mold *Sclerotinia sclerotiorum*	**52**	60	35	26	77	52	61
Alternaria brassicae *Alternaria brassicae, A. brassicola*	**43**	50	42	37	50	35	43

TABLE 21. Frequency of selected diseases of winter oilseed rape in PDO tests in 2015–2020 (% of tests in which plant infection by pathogens occurred); cont.

Disease name	Average	Growing season					
		2020	2019	2018	2017	2016	2015
Stem base diseases *Fusarium* spp., *Verticillium dahliae*, *Phoma lingam* and others	**38**	33	46	33	31	52	35
Powdery mildew *Erysiphe cruciferarum*	**21**	23	15	11	15	13	48
Stem canker *Leptosphaeria maculans*, *L. biglobosa* (*Phoma lingam*)	**14**	10	12	7	12	17	27
Noble rot *Botryotinia fuckeliana*, (*Botrytis cinerea*)	**6**	13	0	0	12	4	4
Downy mildew *Hyaloperonospora parasitica*	**5**	0	4	4	8	4	9

Among the registered oilseed rape varieties, most of them are varieties showing average resistance to infection by the most frequent pathogenic organisms. New varieties generally have good overall health and show increased resistance to at least one disease cause. Unfortunately, these traits are not permanent and can therefore be broken as a result, for example, of strong pathogen pressure. Therefore, many older varieties are more susceptible to particular diseases over time. Increased variety resistance is particularly important in years with a high incidence of disease causes. As a rule, such varieties are affected to a lesser degree and thus respond with a smaller yield reduction.

The availability of winter oilseed rape varieties resistant or tolerant to some pathogens for the needs of integrated oilseed rape protection is currently satisfactory. Every year there are new varieties, which are characterized by high resistance to some pathogenic organisms and additionally they have improved other utility features. **In recent years, there has been a clear increase in the number of varieties that are resistant or tolerant to the perpetrators of economically important diseases, including: clubroot, stem canker and turnip yellows virus.**

A disease that is becoming increasingly prevalent, especially in areas of intensive oilseed rape cultivation, is the clubroot. It is caused by a soil-borne pathogen – the *P. brassicae* protozoa, which can infect various crop species of the *Brassica*, as well as some weeds, including charlock mustard, field pennycress and shepherd's purse – under favourable conditions. Losses in oilseed rape crops caused by clubroot are usually high, and in extreme conditions the disease can cause total yield loss. Unfortunately, in the case of this disease, it is not practical to control the pathogen with known chemical plant protection products. The harmfulness of the clubroot is particularly high, because it has high genetic variability and forms many pathotypes. Furthermore, the spore form of *P. brassicae* retains infective properties in the soil for up to more than 10 years. The most effective method of preventing plant infestations is breeding varieties resistant to *P. brassicae*, and the basic way of limiting the effects of the disease on a specific area is cultivation of such varieties. The availability of varieties resistant to the clubroot is therefore particularly important for oilseed rape growers. Thirteen winter oilseed rape varieties, showing high resistance to the clubroot pathotypes most frequently occurring in Poland, are currently registered in the National List: Alasco, Archimedes, Augusta, Crocodile, Crotora, DK Platinium, DK Plasma, LG Alltamira, LG Anarion, LG Scorpoin, Pegazzus, SY Alibaba, SY Alister. The commercial offer also includes other varieties from the Common Catalogue of Varieties of Agricultural Plants species (CCA), which also show increased resistance to infection by the causes of this dangerous disease (among others: Andromeda, Aristoteles, Cracker, Croquet, Crome, DK Platon, DK Player, DK Pliny, ES Cramberio, LG Alledor, Mendelson, PT235, PT242, PT284, SY Alix).

Currently, seven foreign seed breeding companies offer varieties showing increased resistance to P. brassicae. It is worth knowing that the yielding potential of such varieties is lower than that of non-resistant varieties, although newer varieties already show a higher yielding level. In the event that farm's fields are infected with spores of the clubroot causes, in addition to the cessation of oilseed rape cultivation, an alternative option is to grow resistant varieties. When cultivating such varieties, it is also necessary to have a suitable interval (at least 3-4 years) between cultivation of oilseed rape and other plants from mustard family in the same field, also in order to prevent rapid breakthrough of resistance. In all crops, it is absolutely necessary to destroy weeds that are hosts of the causes of the clubroot and may cause its multiplication (e.g. charlock mustard, wild radish, shepherd's purse, field pennycress, tansy mustard).

One of the most dangerous and widespread diseases of oilseed rape in the world, also in Poland, is the stem canker. This disease is caused by two fungal species of the *Leptosphaeria* (*L. maculans* and *L. biglobosa*). As a rule, oilseed rape plants are infected during the autumn growth period. The pathogen first enters the leaves and then overgrows into the stem. The *L. maculans* is considered to be more damaging species, as infection of the stem causes disruption of the vascular bundles and usually death of the entire plant. *L. biglobosa*, on the other hand, causes extensive disease spots on the stem, but tissue infestation is only on the surface and thus less threatening to plants. Yield losses at high intensity of the pathogen can reach up to 50%. Two types of resistance to the stem canker have been distinguished. Race-specific resistance, so-called vertical resistance, conditioned by single genes, and polygenic resistance, that is, horizontal resistance conditioned by multiple racially non-specific genes. The effectiveness of the latter is sometimes quite variable, but more long-lasting. For several years breeders have been introducing into new hybrid varieties specific genes: *Rlm3, Rlm7, Rlm9* and *Apr37* (*RlmS*), which determine resistance to specific pathotypes, characterized by relatively high resistance to the occurring population of the stem canker causes. Because this type of resistance can be lost as a result of changes in the pathogen population, breeders strive to create varieties that would combine both sources of resistance, i.e. gene-specific and non-specific horizontal resistance. Currently the following winter oilseed rape varieties containing mainly the Rlm7 gene (in isolated cases *Apr37*) are entered in the National List: Absolut, Acapulco, Advocat, Aganos, Akilah, Alvaro KWS, Amazon, Ambasador, Anderson, Angelico, Anniston, Arkansas, Artemis, Augusta, Aurelia, Condor, Desperado, DK Exalte, DK Expiro, DK Exporter, DK Exotter, DK Expansion, DK Expression, DK Exstorm, DK Exssence, DK Extract, Dominator, Duke, Dynamic, ES Barroco, ES Cesario, ES Imperio, INV1188, Kicker, LG Areti, LG Arnold, LG Aviron, Luciano KWS, Riccardo KWS, Roberto KWS, Sergio KWS, Stefano KWS, SY Florida, SY Iowa. The National List also includes varieties with good field resistance to the stem cancer, including Atora, Bonanza, Garou, Popular, SY Cassidy.

It should be borne in mind that oilseed rape varieties containing a specific resistance gene do not completely protect plants against the stem canker infestation. Plant infection occurs in case of a high spore pressure and under favourable infection conditions. Therefore, the use of fungicides recommended for the control of this disease is necessary when warranted. In such cases it is advisable to read the warning about the danger of stem canker infestation and take into account the economic harmfulness thresholds.

In the case of other important oilseed rape diseases of fungal origin (white mold, verticillium wilt, *Alternaria brassicae*), an intensive search is underway for suitable sources of resistance to individual pathogens. Due to the frequency of occurrence, this is particularly important for effective resistance against the white mold and *Alternaria brassicae*. The threat posed by these diseases warrants comprehensive research to obtain varieties with genetic resistance. The identification of appropriate resistance genes, mainly in related species, offers the possibility to introduce them by breeding methods into new varieties. Nevertheless, breeding processes involve an ongoing evaluation of seed in terms of resistance to the main pathogens; only varieties that show improved field resistance are selected.

However, before resistant varieties can be grown, it will be necessary to introduce chemical protection through the use of appropriate fungicides. For example, the control of the dangerous and quite common white mold on oilseed rape plants is most effective when the recommended fungicides are applied during flowering. It is always a good idea to use a variety of decision support systems when planning protection and choosing the right timing for the treatment. Especially since sometimes a well and timely single treatment can also reduce the harmfulness of other diseases.

A big problem that has been occurring in our country for several years is the frequently observed infection of oilseed rape plants with the Turnip Yellow Virus (TuYV). The vector that transmits the virus are aphids, mainly the green peach aphid (*Myzus persicae*), which is a polyphage that feeds on solanaceous plants (potato), bean plants and mustards. The cabbage aphid (*Brevicoryne brassicae*) plays a lesser role in virus infection of oilseed rape plants. Both of those aphids also frequently feed on chemically unprotected catch crops and weeds, from which they move into winter oilseed rape crops. The mass reproduction of aphids during the autumn growth of oilseed rape plants in recent growing seasons may have been caused by relatively high temperatures and a long growing period. In such conditions aphids are active longer and spread viruses to other plantations. Turnip yellows virus has a wide host range and is most prevalent in regions with increased cultivation of oilseed rape, beet, potatoes and vegetables, especially mustards, where aphids feed. Symptoms of infestation of oilseed rape plants are sometimes similar to those caused by nutrient deficiencies (especially nitrogen and phosphorus), also frost damage or root damage by the cabbage fly or the clubroot. Most often on older leaves purple-red (anthocyanin) discoloration can be observed, initially on the edges, and with time covering the entire surface of the blade. Young infected plants also sometimes have undulating leaves. On their underside there are usually aphids, which are the vectors of the virus.

Later there is also a slowing down of growth and gradual dwarfing of plants. At the same time, there is a decrease in the quality of seeds, which contain less fat, while the content of glucosinolates increases. With a severe virus infection, physiological processes of the plant are disrupted. All this causes a significant reduction in yield. On the other hand, varieties with genetically determined resistance to turnip yellows virus under conditions of high aphid pressure and thus threat of infection produce higher and more stable seed yields than non-resistant varieties. It is estimated that an infestation of a plantation with turnip yellow virus can result in a 10-40 percent reduction in seed yield.

Protecting oilseed rape crops from this disease requires effective aphid control, which is not easy to implement with currently available and recommended chemicals. Another option is to breed TuYV-tolerant varieties. Such work is carried out in several foreign breeding centres. The first two such varieties were listed on the National List in 2017, with more to follow in subsequent years, while many others are in registration trials. The following are winter oilseed rape varieties resistant to turnip yellow virus (TuYV) entered into the National List: Absolut, Advocat, Aganos, Akilah, Albrecht, Ambassador, Angelico, Anniston, Architect, Artemis, Aspect, Astana, Attraction, Aurelia, Batis, Chopin, Condor, Daktari, Desperado, DK Excited, Dominator, Duke, Dynamic, Kepler, LE17346, Leona, LG Alltamira (clubroot-resistant), LG Anarion (clubroot-resistant), LG Areti, LG Arnold, LG Avirion, LG Scorpion (clubroot-resistant), Metropol, Prince, Ragnar, Smaragd, SY Floretta, Temptation.

In the case of pests, there are no oilseed rape varieties currently available that have the mechanisms to protect plants from them. Attempts are being made, for example, to breed varieties, whose plants produce a thicker layer of cuticle on the pods and thus are less attractive for a dangerous pest – brassica pod midge. It was found that the first generation of this pest damages varieties that bloom earlier to a greater extent, while the second-generation damages varieties that finish varieties that end blooming late. Another pest of pods, *Ceutorhynchus assimilis*, more often damages the pods of varieties with an earlier flowering stage. The occurrence of both pests on the plants at the same time poses the greatest threat, as openings in the pods caused by weevils are a great advantage for the female brassica pod midge to lay her eggs. On the other hand, observations of damage caused by stem weevils indicate that the damage is greater on the plants of those varieties that develop early and quickly after winter, and smaller on varieties that resume growth later. However, it is estimated that the greatest damage to oilseed rape crops is caused by the common pollen beetle. Beetle feeding initially occurs mainly on the varieties developing earliest in spring, during the flower bud growth period. However, as a rule the greatest damage is caused on late varieties characterised by a longer budding period, when the insect infestation is the most severe.

Therefore, in the case of pests, effective and economically viable protection against their feeding will still be necessary. It is important that if they do occur, their population should be reduced to a level that will not cause excessive yield losses. This is also important due to the fact that plant damage caused by certain pests, e.g. weevils or the brassica pod midge, makes infection by pathogenic fungi more probable.

Over many years, breeding work on oilseed rape has also involved changing its morphological structure. These included both the above-ground part of the plant and the root system. A constant element of this work is increasing the number of pods per plant and seeds in pods, which are the basic yield-forming parameters. In the case of the shoot, its habit was largely changed to the so-called umbrella shape, in which lateral shoots are an important yield-forming element. Plants of new oilseed rape varieties have a less dominant main shoot but produce many lateral shoots that fill the space around them, thus creating a compact canopy architecture in the field. Plants with a changed habit are predisposed to growing in increased spacing, so it is possible to sow oilseed rape seeds in wide rows and in a more precise manner (precision sowing). This type of cultivation will make it possible to carry out inter-row cultivation in the early stages of plant development. On the other hand, a canopy of plants less frequently but more evenly spaced will be better ventilated, and the plants will be less likely to be infected by various pathogens. In breeding and selection work, breeders also pay attention to ensuring that oilseed rape plants produce a strong, well-developed and deep-reaching root system.

Plants with such roots absorb nutrients more intensively (also from deeper soil layers), and better supply the above-ground part of with water even in case of water shortage.

Winter oilseed rape is the most important oilseed crop grown in our country. It has been the subject of intensive breeding work for many years. Numerous new varieties appeared as a consequence. After an appropriate period of conducting research and registration, they are put into production. The annual varieties research conducted within the framework of the Post-Registration Variety Testing System (PDO) allows us to state that new varieties of winter oilseed rape bring breeding progress, which is expressed, among others, by:

- increased fertility,
- increased fat content of the seeds,
- reduction and stabilisation of the glucosinolate content in most varieties,
- the possibility of growing some varieties effectively on medium soils,
- change in plant habit, which also reduces crop lodging,
- reducing the amount of seed sown and the planting density of the crop area,
- increased resistance to infection caused by major pathogens, in particular stem canker (*Phoma*), white mold (*Sclerotinia sclerotiorum*) and *Alternaria brassicae*, as well as the development of new varieties with increased resistance to clubroot and varieties resistant to turnip yellow virus (TuYV)
- increased resistance to pod cracking and seed shedding.

Currently, the main source of breeding progress in oilseed rape cultivation are hybrid varieties. The requirements concerning the necessity of implementing integrated oilseed rape protection, applicable as of 2014, result in the need to breed, and then test and implement cultivation of varieties tolerant and resistant to harmful organisms. The healthiness of oilseed rape varieties is an important criterion for assessing their economic value in the process of registration, and then recommending varieties for wide cultivation.

There is no doubt about the fact that genetic resistance of varieties to diseases is – and will continue to be in the future – an environmentally safe way to maintain the health of field crops of oilseed rape. The widespread use of varieties resistant or tolerant to various adverse factors will bring both economic and environmental benefits.

The traits that determine better productivity under plant stress conditions are also an important element in selecting a variety for cultivation. Oilseed rape growers will more and more frequently for cultivation select varieties which are tolerant to low temperatures, drought and other abiotic stresses, especially in the context of pending climate changes. Also, the quality of the seed yield will always be very important, especially in the case of seeds used in the food industry.

IV.6. AGROTECHNOLOGY AND PATHOGENS

The agrotechnological method consists in the correct and timely execution of all activities related to the structure of sowings, as well as timely and carefully performed tillage. One of the most important methods to reduce the incidence of disease is proper crop rotation. When setting up crop rotations, remember to apply a principle that allows for a certain concentration of plant groups and species in the crop structure and to keep the necessary time gap after which cultivation of the same species can be resumed in a given field.

The longer the break in cultivation of mustards, the viability endospore structures decreases, making soil self-cleaning of pathogenic species more effective. The maximum share of oilseed rape and other plants of the mustard family in the crop rotation should not exceed 25%, and the break in cultivation on the same field should be 3-4 years. This will ensure optimum phytosanitary conditions at the site. The most valuable crop rotation is one with a large number of cultivated species and varieties differing in biological form – spring and winter, length of the growing season, development of the root system, biomass and field architecture, as well as susceptibility to agrophages. Pathogens present on unmineralized crop residues, self-seedings and weeds and as endospore structures – spores, sclerotia or microsclerotia are major causes of infection.

Proper crop rotation is an element of winter oilseed rape cultivation that reduces the incidence of diseases in a cost-effective manner and has a positive effect on on the quantity and quality of the yield. Proper positioning of oilseed rape in the sowing structure has a beneficial effect on the succeeding crops. Winter oilseed rape leaves a very good position for all cereal crops, especially winter wheat and winter barley. Several facts support this arrangement of crop rotation. Firstly, winter oilseed rape belongs to a different family than cereals. In addition, it is harvested early so that the site can be properly prepared for the succeeding crops. There is another argument in favour of growing cereals after winter rape, namely the structure of the root system. Winter oilseed rape has a taproot system and roots deeply, which loosens the deeper layers of soil and extracts nutrients that have been washed into the soil profile. Under these conditions, cereals root deeper and doing better during periodic drought in the spring.

PREVENTION

As part of the application of integrated protection of oilseed rape against causes of diseases, the phytosanitary principles should be applied in accordance with Good Plant Protection Practice. It involves cleaning agricultural equipment, machines used for cultivation, sowing and harvesting, avoiding the combination of seeds from healthy and infected plantations. Careful cleaning of machinery and wheels of plant residues and infected soil is particularly important in reducing plant infestation by the clubroot culprit.

PRECEDING CROP

The use of preceding crops for winter oilseed rape cultivation is quite important. Oilseed rape is one of the plants that require a suitable preceding crop to produce a satisfactory yield. By cultivating oilseed rape after a suitable preceding crop, it will be less exposed to disease infestation, which means that fungicide protection can be significantly reduced. Agricultural crops that can be cultivated before the winter oilseed rape due to their effect on soil were divided into three groups (Table 22). The first group are the best preceding crops. Those include plants from the bean family. Slightly worse preceding crops are potatoes and fodder mixtures. The worst preceding crops for winter oilseed rape are cereals. However, due to the fact that the best and good preceding crops occupy a small area of winter oilseed rape cultivation in the overall sowing structure, the position on which cereals were cultivated is commonly used. A small area of the best and good preceding crops is not the only argument for growing winter rape in succession to cereals. No less important argument in favour of such arrangement of crop rotation is breaking the unfavourable cereal rotation, which is still the case in Polish agriculture.

TABLE 22. Classification of the usefulness of preceding crops for the purpose of maximising the yield potential of oilseed rape and limit the occurrence of diseases

Best preceding crop	Good preceding crop	Worst preceding crop
field bean → edible → field pea → red clover → mixtures of clover and grass → burclover	potatoes → fodder mixtures, both winter and spring	winter cereals: barley → rye → triticale → wheat

Where the risk of clubroot exists or has appeared, crop rotation must be counterchecked. In this case, other mustards (such as mustard – Sinapis) need to be eliminated from crop rotation. It does not matter whether the crops are grown for seed, intercrop biomass for ploughing, mulch or for fodder. A correct, properly composed crop rotation therefore makes it possible to at least partially reduce the pool of pathogenic organisms. After a few years of break in oilseed rape cultivation, the occurrence of pathogens no longer has such a large impact on yield losses and quality.

MONOCULTURE CULTIVATION

Winter oilseed rape is a plant that in some situations and conditions does not react negatively to cultivation in monoculture, but according to the principles of integrated production such a system is unacceptable. First of all, frequent sowing of winter oilseed rape results in reduced yield and poor seed quality. In addition, there is an increased threat from pathogens that cause diseases such as white mold, stem canker and clubroot. Monoculture cultivation often results in one-sided nutrient depletion. Therefore, special attention should be paid to fertilization. Poorly balanced fertilization causes plants to be undernourished, which makes them more affected by disease organisms.

SPATIAL ISOLATION

An important element of the agrotechnological method is the correct location of the crop. When choosing a place to establish crops, in addition to soil conditions, spatial isolation should be considered. It is important to remember not to grow oilseed rape in close proximity to other winter and spring oilseed rape crops, as well as mustard. The maintenance of isolation is related to the possibility of wind-borne spore transmission (e.g. causes of *Alternaria brassicae*, white mold, stem canker, noble rot).

CULTIVATION

Proper management of crop residues by shredding them and mixing with the top soil layer is of great importance in reducing the occurrence of diseases. No matter what tillage system is used at a given farm, the grower should always remember to manage crop residues well. Tillage should be carried out in such a way that mineralization of organic matter is conducted as fast as possible. All tillage measures, irrespective of the technology used, which accelerate the mineralization of crop residues are among the basic and most important methods of integrated pest management. Oilseed rape is a species with a large amount of crop residues remaining in the field after harvesting. They are formed by high stubble field, the pod carpels and a large part of the straw. Appropriate shredding of crop residues and their mixing with an appropriate soil layer significantly reduces the contact of saprotrophs, e.g. the sources of damping off disease, or noble rot with the emerging succeeding plants. Plant fragments infected in the previous growing season are also a major source of primary infection by fungi including the genus Leptosphaeria. Ascomycota spores (ascospores) of these species are formed on infected plant fragments and are capable of infecting plants in the same field. They also transferred by wind to other plantations. Therefore, do not underestimate the cultivation and perform it timely and carefully.

SEED

When growing oilseed rape, it is important to remember that the plantation must be established using good, verified seed. Seed should be certified, because only well-grown, smooth, pathogen-free seeds with high germination strength and vigour guarantee fast and uniform emergence and ensure proper growth and development of plants. Healthy plants are able to compete with weeds and are characterized by greater resistance to pathogens and stress caused by adverse weather conditions such as reduced rainfall or low temperatures. The use of certified seed makes it possible to sow an optimum number of germinating seeds per unit area, which is a basic condition for the proper development of plants before winter rest and, consequently, for good overwintering. Seeds carry a large group of pathogens (e.g. *Phoma lingam, Alternaria* spp., *Botrytis cinerea*, *C. concentricum*), which after sowing cause, together with other microorganisms present in the soil, a damping off disease. In addition, inadequately cleaned seed may also contain endospores of the sources of white mold, noble rot, and weed seed. Therefore, cultivation should be conducted with the use of verified seed.

SOWING

Oilseed rape should be sown in a well-prepared site at the optimum time for a given region, maintaining the sowing rate and depth appropriate to the given variety. This ensures that the emergence is even and the emerging plants develop a strong root system and a sufficient number of leaves. Fast and uniform emergence means that developing seedlings avoid infection by disease organisms. To protect the plantation against diseases, sowing should take place at the optimal time for the region. Too early sowing increases the risk of infestation of oilseed rape with downy mildew, and in some areas also by sources of clubroot. On the other hand, at lower temperatures late sowing favours the development of damping off disease.

The interaction of early and dense sowing is the most unfavourable in terms of diseases. Too high sowing rate results in an overly dense oilseed rape crop. This situation is particularly dangerous under conditions of frequent precipitation, as spores of Alternaria spp., B. cinerea, P. lingam, among others, travel with splashing raindrops and easily reach neighbouring plants. In addition, in a too dense field, high humidity lasts longer, which promotes infection and disease development during growing period. Sowing too early due to the potentially hotter soil, also encourages the development of the sources of the clubroot.

Recent research shows the advantages of precision sowing of oilseed rape in wide rows. Oilseed rape is then healthier, because even plant coverage on the plantation results in better aeration, which in turn reduces pathogen infestation and thus reduces the use of fungicides. In spring, on the other hand, such plants resume growing faster and cope better with drought and pests, which reduces the use of insecticides.

FERTILISATION

The provision of nutrients, both macro- and micronutrients, contributes to the resistance of plants to infestation by fungi that are sources of diseases. Lack of balanced nutrition increases the vulnerability of oilseed rape to both biotic and abiotic stresses. Nutritional deficiencies, especially of elements such as phosphorus, potassium, nitrogen and sulphur, are particularly dangerous in this respect. These elements significantly increase the resistance of oilseed rape to various stresses such as diseases, frostbite, lodging and frost. When growing oilseed rape, it is important to remember that both too little and too much nutrients can negatively affect the occurrence of diseases. For example, too much nitrogen increases the plants' susceptibility to diseases, including attack of the sources of the damping off disease, noble rot and white mold. In turn, the spring application of sulphur has a beneficial effect on improving the health of plants. Soil pH is another factor that significantly affects the plantation health. Proper plant growth as well as nutrient availability are closely related to soil pH. It is important that the soil has the right pH level. The best soils for winter oilseed rape cultivation are slightly acidic to neutral (pH in KCl 5.1-6.5). If the pH is higher, which is rare in Poland, the oilseed rape crops should manage. The situation is slightly different when the site, on which the plantation is established, is acidic. Under such conditions, the development of winter oilseed rape is greatly reduced, and if the pH is very acidic, the plants get sick. It is therefore necessary to systematically check the soil pH and to calcify the field if it drops too low. Improper, i.e. lowered soil pH, promotes infection of plants by *P. brassicae.* If threatened by the source of the clubroot, in order to inhibit the development of its spores, liming should only be carried out before sowing oilseed rape. In the integrated method it is necessary to emphasize the use of organic fertilizers improving the soil structure and enriching it with useful microorganisms.

CARE

A very important element limiting the possibility of diseases is the care of plants during the entire growing period. Plant-care procedures should be performed limiting plant damage. They can be formed by improper herbicide application, pest and game feeding, machinery runs, etc. Any tissue breakage makes plants more predisposed to infection, for example to the sources of noble rot or white mold.

WEED CONTROL

Weed control is paradoxically an important element in reducing disease incidence. Many weed species are indirectly involved in pathogen development. Therefore, in is necessary to fight against them. In addition, weeds further thicken the field, creating favourable conditions for the development of the infestation. It is necessary to eliminate weeds and self-seedings that are hosts to pathogens and transmit or harbour pathogenic organisms that threaten oilseed rape (e.g. clubroot), even if no oilseed rape is grown in a specific field in a given year.

HARVEST

The timing of harvest is also important in terms of obtaining a good quality yield of seed. The seeds should be harvested at the optimum time, as soon as the plants have reached maturity. This is especially important when there is increased humidity, which promotes the development of pathogens on the pods and seeds.

Compliance with all of the above principles ensures that the plants are in good condition and thus less susceptible to pathogen infestation (Table 23). This helps to increase the yield and productivity of the soil, enabling the plants to produce a good quality and quantity winter oilseed rape crop.

TABLE 23. Agrotechnological methods of controlling main winter oilseed rape diseases

Disease	The most important agrotechnological measures of control
White leaf spot	crop rotation; destruction of crop residues; pest control; spatial isolation; correct sowing depth and standard; optimal fertilisation
Cylindrosporiosis	crop rotation; destruction of crop residues; pest control; spatial isolation; correct sowing depth and standard; optimal fertilisation
Alternaria brassicae	crop rotation; destruction of crop residues; spatial isolation of spring varieties from winter varieties; optimal fertilisation; optimal harvesting date
Clubroot	crop rotation; liming before sowing oilseed rape; control of brassica weeds in crops sowed after oilseed rape; regulation of water balance in soil; avoiding too early sowing; thorough cleaning of machinery that was used on infected fields
Powdery mildew	crop rotation; optimum sowing date; correct sowing depth and sowing rate; spatial isolation of spring varieties from winter varieties; optimum fertilisation
Downy mildew	crop rotation; destruction of crop residues; optimum sowing date; correct sowing depth and standard; spatial isolation of spring varieties from winter varieties
Stem canker	crop rotation; destruction of crop residues; pest control; spatial isolation; correct sowing depth and standard; optimal fertilisation
Noble rot	crop rotation; destruction of crop residues; spatial isolation of spring varieties from winter varieties; optimal fertilisation
White mold	crop rotation (avoiding mustards, bean plants, nightshades, sunflower and other hosts) correct sowing rate for certified seed; optimal fertilisation
Damping off disease	crop rotation; optimum sowing date; correct depth and sowing rate; good soil structure; balanced fertilisation

V INTEGRATED PROTECTION AGAINST WEED INFESTATION

V.I. CURRENT AND FUTURE THREATS

Winter oilseed rape is a crop that does not tolerate weeds in the initial period of its development, i.e. from the emergence to the stem elongation stage. This is a period of critical vulnerability to weed infestation. The presence of undesirable plants at this time adversely affects the development of oilseed rape. The occurrence of weeds in this period adversely affects the development of oilseed rape and increases the risk of frost. The best option during autumn growth period is to keep the plantation free of weeds from the emergence stage of oilseed rape plants until the winter rest.

Of all weeds, species with rapid growth and high reproductive potential are the most damaging. In case of winter oilseed rape, the abundance of dicotyledonous weeds usually does not exceed 25-30 species. They do not occur all at the same time – on average their number in one field, depending on the conditions of the habitat and agrotechnology, varies from 4 to 15 species. The most common are overwintering annual species.

Among the dicotyledonous species, the cleavers (*Galium aparine* L.) is considered a nuisance. This is a nitrogen-loving species that thrives in winter oilseed rape plantations when it is not unmanaged. If the oilseed rape crop is contaminated withcleavers seeds, selling to oil mills can be a problem.

Of the other dicotyledonous species, the most common are asters such as: false mayweed (*Matricaria perforata* Mérat), mayweed (*Anthemis arvensis* L.), occasionally chamomile (*Chamomilla recutita* (L.) and pineappleweed (*Chamomilla suaveolens* (Pursh) Rydb.).

In the autumn growth period, as well as in early spring, the following speedwells thrive: ivy-leaved speedwell (*Veronica hederifolia* agg. L.), wall speedwell (*V. arvensis* L.), birdeye speedwell (*V. persica* Poir.). This is also an excellent period for the development of the small bugloss (*Anchusa arvensis* (L.) M. Bieb.).

However, dicotyledonous weeds which may be problematic to control in winter oilseed rape plantations in the upcoming years include species such as geraniums (*Geranium pusillum* L.), common poppy (*Papaverrhoeas* L.) and long-headed poppy (*Papaver dubium* L.), cornflower (*Centaurea cyanus* L.), field pansy (*Viola arvensis* Murray), black-bindweed (*Fallopia convolvulus* (L.) Á. Löve) and brassica weeds such as: tansy mustard (*Descurainia sophia* (L.) Webb ex Prantl) and hedge mustard (*Sisymbrium officinale* (L.) Scop.).

The most common monocotyledonous weed species are common windgrass (*Apera spica-venti* (L.) P. Beauv.), twitch grass (*Alopecurus myosuroides* Huds.), common wild oat (*Avena fatua* L.), winter wild oat (*A. sterilis* L.), couch grass (*Elymus repens* (L.) Gould), and self-seeding cereals. The problem of self-seedings concerns more and more plantations, due to the large share of cereals in the sowing structure and to the fact that in practice most often cereals are plants that precede oilseed rape cultivation. Self-seeding cereals are more of a problem in a no-till farming.

The basic chemical protection of winter oilseed rape against weeds is the autumn application of herbicides. It can be done pre-emergence or after oilseed rape plant emergence.

In most cases, soil-applied herbicides are used. Their effectiveness depends on soil moisture. In case of periodic precipitation deficits (before sowing of oilseed rape or shortly after its emergence) the effectiveness of these measures decreases considerably. Not only is the amount of rainfall important, but also its distribution over time. In recent years there has been considerable variation in the amount of precipitation from year to year, as well as in its distribution from extremely wet to extremely dry conditions. The precipitation is significantly reflected in the dynamics of weed communities development and in the effectiveness of herbicides. In case of dry soil, the effectiveness of soil treatments is lower, and in extreme situations they do not control weeds.

Ongoing climate change also affects the effectiveness of weed control treatments. The increasingly frequent mild and snowless winters often result in increased weed infestation. The basis for protecting winter oilseed rape against weeds are herbicide treatments applied pre-emergence or after oilseed rape emergence during autumn growing period. The occurrence of snowless winters with air temperatures above 3–4°C creates conditions for uninterrupted development and growth of some weed species.

The implementation of the EC Strategy and the withdrawal of herbicide active substances with extended period of effectiveness will affect the efficiency of weed control treatments. In case of a longer growing period before winter rest of winter oilseed rape protected with active substances with a shorter period of effectiveness will result in lower weed control efficiency. The solution to this problem will involve additional herbicide treatments in the fall and sometimes additional corrective treatment in the spring.

The reason for the lack of effectiveness of herbicides may be an improperly selected active substance for the spectrum of weed species present in the field, or the application at the wrong time. For example, when the treatment is performed on weeds in too advanced growth stage. Another reason for reduced or no efficiency may be the development of weed resistance to the herbicide active substance that previously controlled that weed species.

The problem of occurrence of weed biotypes resistant to herbicides is a major one. So far in Poland, the occurrence of the following populations of herbicide-resistant weed species: common windgrass (*Apera spica-venti* (L.) P. Beauv.), witch grass (*Alopecurus myosuroides* Huds.), common wild oat (*Avena fatua* L.), cornflower (*Centaurea cyanus* L.), false mayweed (*Matricaria perforata* Merat) and common poppy (*Papaver rhoeas* L.) has been confirmed. The occurrence of herbicide-resistant weed biotypes includes species with a high reproductive rate whose seeds can be spread easily.

One of the factors favouring the development of weed resistance to herbicides is inappropriate weed control based only on common use of herbicides without taking into account other methods, especially agrotechnological.

The risk of developing resistance to herbicides increases when herbicides from the same chemical group or with the same mode of action are used periodically.

To counteract the risk of growing herbicide-resistant weeds, herbicides with a different mode of action or at least from different chemical groups should be used alternately.

For this purpose, when selecting an herbicide for treatment, se a table classifying herbicides according to their mode of action (Table 24), based on the HRAC (Herbicide Resistance Action Committee) classification. The letter codes are assigned to different modes of action of herbicides in accordance with HRAC classification.

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TABLE 24. Mode of action, International Herbicide Resistance Action Committee classification, chemical groups and active substances of herbicides recommended for winter oilseed rape

Mode of action	Group in according to HRAC*	Chemical group	Active substances currently registered	Active substances to remain following a negative evaluation of the substances proposed for substitution
Acetyl CoA carboxylase (ACCase) inhibitors	A	arylphenoxy propionic acid derivatives (group -FOP)	quizalofop-p-ethyl quizalofop-p-tefuryl fluazifop-p-butyl haloxyfop-p propaquizafop	quizalofop-p-ethyl fluazifop-p-butyl propaquizafop
		cyclohexanedione (group -DIM)	cycloxydim clethodim	cycloxydim clethodim
Acetolactate synthase (ALS) inhibitors	B	imidazolones	imazamox	-
Protoporphyrinogen oxidase (PPO) inhibitors	E	diphenyl ethers	bifenox	bifenox
Carotenoid biosynthesis inhibitors	F3	isoxazolidines	chlomazone	chlomazone
EPSP inhibitors	G	aminophosphonates	glyphosate	-
Microtubule formation inhibitors	K1	benzamides	propyzamide	-
Very long chain fatty acids (VLCFA) biosynthesis inhibitors	K3	chloroacetanilides	dimethachlor	dimethachlor
			dimethenamid-p	dimethenamid-p
			pethoxamid	pethoxamid
			metazachlor	metazachlor
		acetamides	napropamide	napropamide
Synthetic auxins	O	pyridinecarboxylic acid derivatives	aminopyralid clopyralid picloram	aminopyralid clopyralid picloram
		quinolinecarboxylic acid derivative	quinmerac	quinmerac
		aryl-picoline compounds	halauxifen-methyl	halauxifen-methyl

* HRAC classification systematizing active substances of herbicides according to their mode of action.

V.2. WITHDRAWN ACTIVE SUBSTANCES

In winter oilseed rape, 22 active substances of herbicides are registered for weed control during oilseed rape growing period, of which 2 active substances can also be applied before oilseed rape sowing (Tab. 25).

TABLE 25. Current status of registration of chemical active substances of herbicides used in oilseed rape cultivation (May 20, 2021)

Active substance (AI)	Expiry date in the EU	Substance to be replaced/ withdrawn from the market	Number of herbicides with a given AI registered in winter oilseed rape cultivation
Aminopyralid	31/12/2024	no	8
Bifenox	31/12/2021	no	1
Quinmerac	31/07/2024	no	20
Quizalofop-P-ethyl	30/11/2021	no	31
Quizalofop-p-tefuryl	30/11/2021	yes	4
Chlomazone	31/10/2021	no	44
Clopyralid	30/04/2022	no	32
Cycloxydim	31/05/2023	no	1
Dimethachlor	31/12/2021	no	4
Dimethenamid-P	31/08/2034	no	10
Fluazifop-p-butyl	31/12/2023	no	12
Glyphosate	15/12/2022	no	54
Halauxifen-methyl	05/08/2025	no	3
Haloxyfop-p	31/12/2020 brak zatwierdzenia	yes	2
Imazamox	31/01/2025	yes	4
Clethodim	31/05/2023	no	5
Metazachlor	31/07/2021	no	56
Napropamide	31/12/2023	no	12
Pethoxamid	30/11/2033	no	4
Picloram	31/12/2021	no	20
Propaquizafop	30/11/2021	no	7
Propyzamide	30/06/2025	yes	8

In accordance with Regulation (EC) No. 1107/2009; (EU) 2015/408 and (EU) 2018/755, as of 2018, the European Union is withdrawing from the catalogue of available active substances those that meet the criteria to be considered persistent and toxic.

Of the currently registered herbicide active substances in winter oilseed rape, agents containing haloxyfop-P will be withdrawn first. Commercial products based on this substance placed on the market until 28 February 2021 may be sold and distributed until 28 August 2021, and their final use period expires on 28 August 2022.

More herbicide active substances may be withdrawn in the coming years (Table 25). The approval of the active substance quizalofop-P-tefuryl expires on 30 November this year and of the active substances imazamox and propyzamide in 2025. Products containing the active substance imazamox are intended for the control of dicotyledonous and certain monocotyledonous weeds only in oilseed rape varieties resistant to the active substance imazamox. This is an important active substance which makes it possible to control, among others, troublesome brassica weeds which appear more and more frequently, such as: tansy mustard (*Descurainia sophia* (L.) Webb ex Prantl), hedge mustard (*Sisymbrium officinale* (L.) Scop.).

Although most oilseed rape weed control active substances are not qualified for substitution, it is noteworthy that the approval of seven active substances (bifenox, quizalofop-P-ethyl, clomazone, dimethachlor, metazachlor, picloram, propaquizafop) expires this year. The approval of the active substance clopyralid expires in 2022 and of a further four active substances (cycloxydim, fluazifop-p-butyl, clethodim, napropamide) in 2023. The lack or non-renewal of further approval of these active substances could reduce the effectiveness of oilseed rape weed control.

V.3. SUBSTITUTES FOR WITHDRAWN ACTIVE SUBSTANCES

In winter oilseed rape (as of 25 May 2021), 273 herbicides for weed control are currently registered, including 54 based on the active substance glyphosate. Herbicides containing glyphosate AIs are intended for use prior to harvest to control weeds that prevent harvest. Most of them are also recommended for post-harvest weed control prior to post-harvest cultivation – this treatment is most commonly used in no-till.

Withdrawal of active substances qualified for substitution will not negatively influence the efficiency of winter oilseed rape weed control (Tab.26 and 27).

TABLE 26. Examples of weed control options for substituted active substances following changes to be introduced by EC

Active substance	Weed species under control	Examples of active substances and their mixtures for the protection of oilseed rape to remain following the negative assessment of the proposed substitutes
Quizalofop-p-tefuryl	annual monocot weeds, self-seeding cereals, couch grass	quizalofop-p-ethyl, cycloxydim, clethodim, propaquizafop
Haloxyfop-p	annual monocot weeds, self-seeding cereals, couch grass	quizalofop-p-ethyl, cycloxydim, clethodim, propaquizafop
Imazamox	self-seeding cereals, annual monocot weeds	chizalofop-p-etylowy, cykloksydym, propachizafop
	dicot brassica weeds	metazachlor, clomazone + napropamide, halauxifen-methyl + picloram, metazachlor + aminopyralid + picloram, clomazone + dimethachlor, napropamide
Propyzamide	monocot weeds	quizalofop-p-ethyl, cycloxydim, propaquizafop
	dicot weeds	metazachlor, pethoxamid

TABLE 27. Sensitivity of weeds to active substances of herbicides recommended for winter oilseed rape

Active substance	aminopyralid	bifenox	chlomazone	clopyralid	dimethachlor	metazachlor	napropamide	pethoxamid	picloram	propyzamide	graminicides
Common ragweed				s							n
Fool's parsley								s			n
Small-flowered crane's-bill		m	s					s		s	n
Cornflower	s	m		s					s		n
Cockspur grass	n	n	s	n	n	s	m	s	n	s	s
Common fumitory			m	s			n	m		n	n
Small bugloss		s	s					s			n
Field pansy	m	s	n	n	n	m	n	m	n	n	n
Charlock mustard			m	n	m	m	m	s		m	n
Chickweed		s	s		s	s	s	m	m	s	n
Redstem filaree							s				n
Red dead-nettle	n	s	s		s	s	n	s	m	m	n
Lamb's quarters		s	m		s	s	s	m	n	m	n
Common poppy	s	s		s	m	s		n	m	m	n
False mayweed	s	s	m	s	s				s	n	n
Common windgrass		n			s	s	m	s		s	s
Field milk thistle				s		s			s		n
Dandelion										n	n
Myosotis arvensis					s	s					n
Creeping thistle				s	n	n			s	n	n
Common wild oat	n	n	n	n	n	n	n	n	n	s	s
Couch grass	n	n	n	n	n	n	n	n	n	m	s
Ivy-leaved speedwell		s	m			s			n	s	n
Birdeye speedwell		s	m		s	s		s	n	s	n
Wall speedwell			m							s	n
Cleavers		s	s		n	s	m	n	s	m	n
European black nightshade			m	s			n	s			n

TABLE 27. SENSITIVITY OF WEEDS TO ACTIVE SUBSTANCES OF HERBICIDES RECOMMENDED FOR WINTER OILSEED RAPE; cont.

Active substance	aminopyralid	bifenox	chlomazone	clopyralid	dimethachlor	metazachlor	napropamide	pethoxamid	picloram	propyzamide	graminicides
Common knotgrass			m	s			m			s	n
Pale persicaria		s		s		m	m			s	n
Black-bindweed		s	m			m	m	m		s	n
Corn chamomile		m	m	s	s	s	s	s	s	n	n
Chamomile	s		m	s	s	s	s		s	n	n
Wild radish				n	m	n				s	n
Self-seeding cereals	n	n	n	n	m	m	m			s	s
Groundsel				s			s			n	n
Bromes	n	n	n	n		n				s	s
Red-root amaranth			m				s	s		m	n
Shepherd's purse	n	s	s	n		s	m	m	n	n	n
Field pennycress		s	s	n		m		m		m	n
Annual meadow grass		n	m		s	s	s			s	n
Sun spurge						n		m		m	n
Slender meadow foxtail		n			s	s					s
Potato weed			m	s		s				n	n

[w] – sensitive species; [s] – medium sensitive species; [n] – non-sensitive species; blank – no data

*graminicides: quizalofop-p-ethyl, quizalofop-p-tefuryl, cycloxydim, fluazifop-p-butyl, haloxyfop-p, propaquizafop

V.4. AGROTECHNOLOGY AND WEED CONTROL

Properly planned agrotechny is important for weed control. Many factors influence the number of weed species and their intensity of occurrence in the crop. In most cases, weed infestation is a reflection of the amount of active diaspores (seeds, rhizomes, stolons, tubers, bulbs) of weeds in the soil. Their number depends to a large extent on the crop rotation and the agrotechnological measures carried out. The intensity of treatments and simplifications (crop rotation, cultivation) has a significant impact on the qualitative and quantitative composition of weed infestation. In winter oilseed rape cultivation, the period from harvesting the preceding crop to sowing is relatively short. Weather conditions during this short period of time are often not favourable for post-harvest cultivation – it is too dry or excessively wet. In addition, during this time there is usually a flurry of field work.

Cereals are the most common preceding crops for winter oilseed rape. As far as agrotechnological measures implemented after harvesting the preceding crop are concerned, ploughing has an effect on reducing the weed infestation with self-seeding cereals and some weed species, however it does not fully solve this problem and does not replace direct methods of weed control, among which the chemical method is the most commonly used.

Mechanical weed control is currently of limited use in oilseed rape cultivation. Harrowing of oilseed rape is usually not recommended, and assessments of the usefulness of these treatments are controversial, among other things due to the risk of damage to the root collar of oilseed rape plants. Mechanical damage to oilseed rape plants increases the risk of infection by the sources of stem canker, white mold and noble root, among others.

Of the mechanical methods of direct weed control, mechanical weeders can be useful. At present, mechanical weed control in oilseed rape cultivation is used sporadically and, if applied, only on small farms. Popularisation of mechanical weeding of oilseed rape crops on a larger scale will be connected with the development and popularisation of modern, technologically advanced weeders equipped with automatic or autonomous guidance of weeder working units on the basis of images from cameras installed on the weeder, GPS signals and other solutions influencing the precision of these tools.

VI REGULATORS AND BIOSTIMULANTS

VI.I. PLANT GROWTH AND DEVELOPMENT REGULATORS

Previous studies on the use of regulators indicate that oilseed rape plants are susceptible to modification of growth and development. However, it is important to pay attention to the interaction between plantation ripeness, the stage of the plants' development at the time of treatment, and the results obtained. There is a high correlation between the size of oilseed rape plants at the time of application of the regulator and the effectiveness of its action on individual characteristics of plant growth and development.

APPLICATION TIMING OF PLANT GROWTH AND DEVELOPMENT REGULATORS

The timing of the treatment may be decisive in whether or not the expected results will be achieved. Plant growth and development regulators applied in the fall increase the winter hardiness of plants by reducing shoot growth and apical bud growth. On the other hand, when applied in spring, they reduce crop lodging and change crop habit, thus enabling the maximum use of yield potential of plants. The right timing of growth regulator application is critical to achieving the desired trait value (e.g. stem shortening). Spring application of growth regulators in oilseed rape cultivation should be closely correlated with its developmental stage. Application of the growth regulator at the beginning of the stem elongation stage results in an increased reduction in plant height and limits lodging to a larger extent than in the case of application at a later time (green bud stage).

CROP DENSITY AND THE USE OF PLANT GROWTH AND DEVELOPMENT REGULATORS

One of the major factors affecting the large disproportion between the yield potential of oilseed rape and the actual yield obtained is the implementation of a cultivation system characterised by high crop density, which results in the plants shading each other and preventing light penetration. This is applicable particularly during flowering, as the oilseed rape inflorescences absorb and reflect around 60% of the light falling on the plants, as a result of which the lower situated pods are not as well formed and do not yield a sufficient number of seeds and therefore do not use their full yield potential. In addition, in case of high density crops pods are often damaged to a greater extent. In contrast to cereals, oilseed rape leaves are far less important in the process of yield formation. The dominant yield-forming apparatus is seed pods. It is therefore necessary to establish appropriate growing conditions for oilseed rape, which includes modification of plant habit, so that the seed pods can develop as well as it is possible. It is assumed that the optimum number of pods to ensure a high yield is 6000 pieces per 1 square meter of plantation. Another problem related to the morphological structure of oilseed rape and its cultivation technology is the risk of lodging. Oilseed rape plants are tall and highly branched at the top, therefore the plants not only shade each other, but are also susceptible to lodging, especially when there is heavy rainfall during the period pods ripening. The high density of oilseed rape plants and the high nitrogen fertilization contribute to an increased risk of lodging.

OVERVIEW OF PLANT GROWTH AND DEVELOPMENT REGULATORS

Several substances are available on the market that effectively regulate the growth and development of oilseed rape. Substance overview with examples of commercial products is presented in Table 28.

TABLE 28. Examples of plant growth and development regulators recommended for winter oilseed rape*

STABILAN 750 SL
Active substance: chlormequat chloride (a quaternary ammonium salt) – 750 g/l (65.56%)
Dose: 0.5-0.75 l/ha
Application: in autumn, at the stage of leaf development when 4-6 leaves are unfolded (BBCH 14–16).
Effect on the plant: stunts growth and reduces lodging of winter oilseed rape, increases the number of branches and pods per plant, which has a positive effect on yield.
CEKWAT 750 SL
Active substance: chlormequat chloride (a quaternary ammonium salt) – 750 g/l (65.56%)
Dose: 0.5-0.75 l/ha
Application: in autumn, at the stage of leaf development when 4-6 leaves are unfolded (BBCH 14-16).
Effect on the plant: stunts growth and reduces lodging of winter oilseed rape, increases the number of branches and pods per plant, which has a positive effect on yield.

TABLE 28. Examples of plant growth and development regulators recommended for winter oilseed rape*; cont.

CHLOREKMOC
Active substance: chlormequat chloride (a quaternary ammonium salt) – 750 g/l (65.56%)
Dose: 0.5-0.75 l/ha
Application: in autumn, at the stage of leaf development when 4-6 leaves are unfolded (BBCH 14-16).
Effect on the plant: when applied in autumn, it stunts growth and reduces lodging of winter oilseed rape, increases the number of branches and pods per plant, which has a positive effect on yield.
MIDAS DUO 250 EC
Active substance: trinexapac-ethyl (a cyclohexanedione) – 250 g/l (25.5%).
Dose: 1.5 l/ha
Application: at the stage of leaf development when 4-8 leaves are unfolded (BBCH 14-18).
Effect on the plant: when applied in autumn: improves winter hardiness of plants by stimulating the root system and inhibiting stem growth, when applied in spring: should be used from the main shoot elongation stage (one visible extended internode) to the beginning of oilseed rape flowering (BBCH 31-59); spring application of the product prevents stem elongation and results in plant stiffening, which reduces the risk of lodging.
MEROS 250 EC
Active substance: trinexapac-ethyl (a cyclohexanedione) – 250 g/l (25.5%).
Dose: 1.5 l/ha
Application: from the end of the main shoot growth/elongation stage (9 or more visible extended internode) to the end of flower bud development on the main inflorescence (individual flower buds visible but closed) (BBCH 39-55).
Effect on the plant: used to prevent lodging of winter oilseed rape, spring oilseed rape and winter oilseed rape grown with the use of intensive technologies, with a high level of nitrogen fertilization.
POWER GRAIN 250 EC
Active substance: trinexapac-ethyl (a cyclohexanedione) – 250 g/l (25.5%).
Dose: 1.5 l/ha
Application: from the end of the main shoot growth/elongation stage (9 or more visible extended internode) to the end of flower bud development on the main inflorescence (individual flower buds visible but closed) (BBCH 39-55).
Effect on the plant: used to prevent lodging of winter oilseed rape, spring oilseed rape and winter oilseed rape grown with the use of intensive technologies, with a high level of nitrogen fertilization.

TABLE 28. Examples of plant growth and development regulators recommended for winter oilseed rape*; cont.

Moddus 250 EC
Active substance: trinexapac-ethyl (a cyclohexanedione) – 250 g/l (25.5%).
Dose: 1.5 l/ha
Application: during growth stage, from the end of the main shoot growth/elongation stage (9 or more visible extended internode) to the end of flower bud development on the main inflorescence (individual flower buds visible but closed) (BBCH 39-55).
Effect on the plant: product belonging to the plant growth regulator group, used to prevent lodging of crops grown with the use of intensive technologies, with a high level of nitrogen fertilization; it is absorbed mainly by the leaves and then transferred to meristematic tissues, thus preventing excessive internode elongation. It does not reduce root length or plant weight. The intensity of the results of the product application depends on the stage of the crop development, varieties, site and weather conditions. The strongest shortening is after the second application observed in intensively elongating internodes. Tall varieties react to the product with a stronger shortening of internodes.
PROTEG 250EC
Active substance: trinexapac-ethyl (a cyclohexanedione) – 250 g/l (25.5%).
Dose: 1.5 l/ha
Application: from the end of the main shoot growth/elongation stage (9 or more visible extended internode) to the end of flower bud development on the main inflorescence (individual flower buds visible but closed) (BBCH 39-55).
Effect on the plant: prevention of lodging of winter oilseed rape.
SONIS
Active substance: trinexapac-ethyl (a cyclohexanedione) – 250 g/l (25.5%).
Dose: 1.5 l/ha
Application: from the end of the main shoot growth/elongation stage (9 or more visible extended internode) to the end of flower bud development on the main inflorescence (individual flower buds visible but closed) (BBCH 39-55).
Effect on the plant: prevention of lodging of winter oilseed rape.
TRI - TURBO 250 EC
Active substance: trinexapac-ethyl (a cyclohexanedione) – 250 g/l (25.5%).
Dose: 1.5 l/ha
Application: from the end of the main shoot growth/elongation stage (9 or more visible extended internode) to the end of flower bud development on the main inflorescence (individual flower buds visible but closed) (BBCH 39-55).
Effect on the plant: prevention of lodging of winter oilseed rape.

TABLE 28. Examples of plant growth and development regulators recommended for winter oilseed rape*; cont.

CARYX 240 SL
Active substances: mepiquat chloride (a piperidine/ pentamethyleneimine) – 210 g/l (19.1%), metconazole (a triazole) – 30 g/l (2.7%).
Dose: autumn: 1.0 l/ha, spring: 1.0-1.4 l/ha
Application timing: when applied in autumn: spray oilseed rape plants at the stage of leaf development when 4-6 leaves are unfolded (BBCH 14-16), autumn treatment results in a change in plant habit, stimulation of the root system, the formation of a compact rosette of leaves and inhibition of stem growth, which in turn improves winter hardiness of oilseed rape plants and increases seed yield, when applied in spring: spray oilseed rape plants at the beginning of the main shoot elongation stage (BBCH 32-35).
Effect on plants: product belonging both to the plant growth and development regulators and the fungicides group, in the form of a water-soluble concentrate with systemic action for preventive, emergency and destructive use in the cultivation of winter oilseed rape against fungal diseases; it contains two active substances: mepiquat chloride, which inhibits the biosynthesis of gibberellins, which in consequence results in the formation of compact rosette (shoot with leaves) in the autumn, just above the ground; such crops are characterized by greater resistance to frost and better development in the spring period; metconazole, which fights fungal diseases and additionally acts as a growth regulator.
MEPIK 300 SL
Active substance: mepiquat chloride (a piperidine) – 300 g/l (28.76%).
Dose: spring: 0.6–0.7 l/ha, 1. autumn: 0.5 l/ha – 2. spring: 0.4 l/ha – mixtures
Application: when used in spring: during the growth (elongation) of the main shoot up to the stage when 5 internodes are visible (BBCH 30-35); when used in autumn: at the stage of leaf development when 2-8 leaves are unfolded (BBCH 12-18), however, in order to obtain the maximum effect it is recommended to carry out treatment at the stage of leaf development when 4-6 leaves are unfolded (BBCH 14-16).
Effect on plants: product belonging both to the plant growth and development regulators and the fungicides group, in the form of a water-soluble concentrate with systemic action, prevents excessive plant overgrowth and supports shortening and strengthening of stems in spring with a long application timing, which covers autumn and spring application in oilseed rape and spring application in cereals, enables effective cultivation of winter oilseed rape, also at lower temperatures, causes oilseed rape crop to grow evenly.
INVISTER 300 SL
Active substance: mepiquat chloride (a piperidine) – 300 g/l (28.76%).
Dose: spring: 0.6–0.7 l/ha, autumn: 0.5 l/ha
Application: when used in spring: during the growth (elongation) of the main shoot up to the stage when 5 internodes are visible (BBCH 30-35). Should be applied twice per growing season. When used in a mixture: the first treatment should be conducted in autumn, at the stage of leaf development when 2-8 leaves are unfolded (BBCH 12-18), however, in order to obtain the maximum effect it is recommended to carry out treatment at the stage of leaf development when 4-6 leaves are unfolded (BBCH 14-16).
Effect on plants: plant growth and development regulator in the form of a water-soluble concentrate (SL) with systemic action to prevent excessive plant outgrowth and to shorten and strengthen stems (reduce lodging).

TABLE 28. Examples of plant growth and development regulators recommended for winter oilseed rape*; cont.

REGULATO 300SL
Active substance: mepiquat chloride (a piperidine) – 300 g/l (28.76%).
Dose: 0.6-0.7 l/ha
Application: when used in spring: during the growth (elongation) of the main shoot up to the stage when 5 internodes are visible (BBCH 30-35);
Effect on plants: plant growth and development regulator in the form of a water-soluble concentrate (SL) with systemic action to prevent excessive plant outgrowth and to shorten and strengthen stems (reduce lodging).
TOPREX 375 SC
Active substances: difenoconazole (a triazole) – 250 g/l (22.5%), paclobutrazol (a triazole) – 125 g/l (11.3%)
Dose: autumn: 0.3 l/ha. spring: 0.35 l/ha
Application: when used in autumn: at the stage of leaf development when 4-6 leaves are unfolded (BBCH 14-16), when used in spring: during the growth (elongation) of the main shoot up to the stage to moment when individual flower buds are visible on the main inflorescence (BBCH 31-55).
Effect on plants: fungicide and plant growth and development regulator in the form of a water-soluble concentrated suspension (SC), to be used for preventive and emergency purposes, to prevent excessive plant overgrowth and lodging and to protect plants against fungal diseases
MAGNELLO 350 EC
Active substances: difenoconazole (a triazole) – 100 g/l (9.9%), tebuconazole (a triazole) – 250 g/l (24.8%)
Dose: 0.8 l/ha per growing season: 2 treatments (one in autumn and one in spring), interval between treatments: 90 days
Application: when applied in autumn: at the stage of leaf development when 4-8 leaves are unfolded (BBCH 14-18), improves winter hardiness of plants by stimulating the root system and inhibiting stem growth, when applied in spring: should be used from the main shoot elongation stage (one visible extended internode) to the beginning of oilseed rape flowering (BBCH 31-59); spring application of the product prevents stem elongation and results in plant stiffening, which reduces the risk of lodging.
Effect on plants: fungicide in the form of a concentrate for preparing an aqueous emulsion, to be used for preventive and emergency purposes, designed to protect winter oilseed rape, spring oilseed rape, winter agrimony, brown mustard, white mustard and black mustard against fungal diseases, as well as to prevent excessive plant outgrowth in the autumn and shortening and strengthening of stems in the spring.

TABLE 28. Examples of plant growth and development regulators recommended for winter oilseed rape*; cont.

ASAHI SL
Active substances: sodium p-nitrophenolate (a nitrophenol derivative) – 0.3% (3 g in 1 litre of the product); sodium o-nitrophenolate (a nitrophenol derivative) – 0.2% (2 g in 1 litre of the product); sodium 5-nitroguaiacolate (a nitrophenol derivative) – 0.1% (1 g in 1 litre of the product).
Dose: 0.6 l/ha
Application: from the beginning of stem elongation until the end of flowering
Effect on plants: increases yield and improves crop quality, to be used when plants are subjected to stress conditions which are not conducive to plant growth e.g. drought, frost and after planting or in the case of plant damage e.g. by plant protection products or fertilizers.

*Based on labels

CHLORMEQUAT CHLORIDE, MEPIQUAT CHLORIDE AND TRINEXAPAC-ETHYL

These substances, although from different chemical groups, show a similar mode of action. They inhibit the synthesis of enzymes necessary for the biosynthesis of gibberellins in the plant and hence are popularly known as anti-gibberellins. The visible effects of trinexapac-ethyl, chlormequat chloride and mepiquat chloride usage are the reduced height and strengthened stems of the plants, resulting in increased resistance to lodging. These substances are widely used to protect cereals and oilseed rape against lodging. The best effects of these substances are obtained when applied at temperature of 10–15°C.

TRIAZOLES (METCONAZOLE, DIFENOCONAZOLE, PACLOBUTRAZOL, TEBUCONAZOLE)

These are systemic fungicides that, in addition to their fungicidal properties, have significant potential to regulate crop habit, the effects of which are particularly evident after spring treatments are carried out. Their mode of action involves conversion of lanosterol to ergosterol in pathogenic fungi and ent-kaurene to ent-kauronic acid (precursor of gibberellins). Triazole-treated plants have darker leaves due to increased levels of chlorophyll and carotenoids. An additional function of triazoles in the plant is their effect on increasing low and high temperature tolerance (thermoregulation).

Unfortunately, metconazole, tebuconazole, paclobutrazol and difenoconazole, although still available, are scheduled by the European Commission for withdrawal in the near future. This will significantly narrow the range of substances available to regulate the growth and development of oilseed rape.

VI.2. BIOSTIMULANTS

Biostimulants are substances that, when applied to the plant or the soil, show positive effects on growth, development and plant tolerance to biotic and abiotic stresses.

Biostimulants may be of natural or synthetic origin. Among the substances which exert a particular effect on oilseed rape plants are algae, amino acids, plant hormones, vitamins (mainly from the B group), substances of organic origin (e.g. humic and fulvic acids, leonardite), polysaccharides, phenols, allelochemicals. Many commercial products additionally contain macro- and micronutrients, which further enhance the yield potential of the plants.

BIOTIC AND ABIOTIC STRESSES IN PLANT LIFE

Plants during their growth period are subjected to various biotic and abiotic stresses. Biotic stresses are factors from animate nature (pathogens, weeds, pests), while abiotic stresses are the result of environmental factors (drought, salinity, high or low temperature). Crops respond particularly negatively to abiotic stress. Any stress causes a number of changes in plants, some of which are reversible and some of which unfortunately result in plant death. In our climate, the most important stress factors are high and low temperatures and drought. They lead to physiological, morphological, ecological, biochemical and molecular changes in plants. The response of plants to this factor depends on the age of the species (sometimes also the variety), the age of the plant and its developmental stage. In the case of oilseed rape, an extremely important type of stress is the temperature factor occurring in autumn and related to sudden cold and frost.

THE IMPORTANCE OF BIOSTIMULANTS

In order to protect oilseed rape plantations from unfavourable environmental conditions and to ensure optimal development parameters of the plant, biostimulants are used more and more often. The application of biostimulants to plants strengthen their natural resistance to many stress factors. A properly functioning plant organism is able to activate natural immune processes against pathogens and pests. Soil-applied biostimulants strengthen the root system of the plant, so that the plant can compete with weeds for water and nutrients. A common feature of biostimulants is that they are usually administered in small amounts sufficient to stimulate the plant organism and help it adapt to environmental conditions. Nowadays, in the view of changing climate and related adverse weather events, changes in the number of generations of pests attacking crops, the emergence of new thermophilic agrophages (pests, weeds), the use of biostimulants is considered a necessary element of plant production. The use of biostimulants is associated with a modern approach to the regulation and modification of physiological processes occurring in the plant. This modification is aimed primarily at maintaining stable crop yields even under stress conditions. Biostimulants stimulate root system growth under conditions of poorly fertilized soils and low water availability. Their application contributes to a significant strengthening of seedlings, which gain physiological resistance in such conditions. Biostimulants, especially those of organic origin, also contribute to reducing the number of fertilizer applications.

CONDITIONS FOR THE USE OF BIOSTIMULANTS

A very important element of biostimulants application is the developmental stage of the crop and the overall condition of the plants at the time of treatment. Application of biostimulants on very weak plants, damaged by environmental stress factors may not bring the expected results. This is due to the already weak metabolism of the plant, which will not be able to properly assimilate and process the supplied substances. The ideal situation would be to apply biostimulants before the expected stress factors occur, but it can often be difficult to determine the likelihood of their occurring, so the general rule should be to make biostimulants a permanent part of the protection program. Table 29 provides examples of biostimulants recommended for winter oilseed rape*.

TABLE 29. Examples of biostimulants recommended for winter oilseed rape*

ALGEX
Ingredients: *Ascophyllum nodosum algae* extract Content of elements: nitrogen – 8%, phosphorus – 3.6%, potassium – 7%, boron – 0.036%, zinc – 0.025%, copper – 0.009%, iron – 0.016%, manganese – 0.036%, molybdenum – 0.0036%.
Dose: 4-5 l/ha
Application: after spring growth period starts, after flower buds form, beginning of flowering
Effect on plants: stimulates mineral nutrition of plants, stimulates the process of flower fertilisation and fruit setting, activates vital plant processes in situations when plants are subjected to stress factors, has a favourable effect on cell division and fruit growth, prevents fruit deformations.
AMINOGAL
Ingredients: free L-amino acids (19 active amino acids) – 11.0%, total nitrogen – 8.5%, organic nitrogen – 6.0%, inorganic nitrogen – 2.5%, potassium oxide K2O – 1.0%, organic carbon – 24.0%, organic matter – 40.0%.
Dose: 1.0-1.5 l/ha
Development stage: at the stage of leaf development when 8-10 leaves are unfolded
Effect on plants: activates important enzymes and accelerates the growth and development of the plant in a natural way, intensifies photosynthesis processes, quickly regenerates the plant subjected to stress factors (drought, frost, hail), stimulates plant growth, improves crop size and quality, accelerates the absorption of fertilizers and pesticides, ensuring their higher effectiveness.
BASFOLIAR KELP P MAX
Ingredients: 4.0% – N total nitrogen, of which: 4.0% – N-NH_2 amide nitrogen, 6.0% – P_2O_5 water-soluble phosphorus pentoxide, 2.0% – K_2O water-soluble potassium oxide.
Dose: 2-4 l/ha
Application: in autumn (at the stage of leaf development when 3-5 leaves are unfolded), in the spring after the start of growth period.
Effect on plants: increases resistance of plants to diseases and stress factors, has a positive impact on the health of plants, accelerates the regeneration of plants, enhances the process of photosynthesis in plants, strengthens the root system, accelerates the absorption of components, stimulates vegetative and generative parts of plants to growth.
BASIC POWER
Ingredients: microelements (Fe 1.2%; Mn 0.6%; Zn 0.7%), amino acids 42.6% (15% of which are levorotatory) and organic nitrogen – 7.6%.
Dose: 1-2 l/ha
Application: spray mixed with pesticides or during treatment with chemical plant protection products; treatments should be carried out in autumn and in spring, just after the growth resumes; to be applied before flowering of oilseed rape.
Effect on the plant: the plant becomes more tolerant to frost, can survive longer without water, reduces the effects of drought, allows faster regeneration of plants after heavy rain and hail, additionally contains essential microelements and a large dose of nitrogen.

TABLE 29. Examples of biostimulants recommended for winter oilseed rape*; cont.

BIO FOL PLEX
Ingredients: total nitrogen (N) – 2.00% (m/m), magnesium – 0.30% (m/m), sulphur – 5.00% (m/m), boron – 0.15% (m/m), copper – 0.05% (m/m), iron – 0.20% (m/m), manganese – 0.10% (m/m), zinc – 0.50% (m/m), carbon – 1.25% (m/m), algae extract – 5.00% (m/m), trace amounts of plant hormones, trace amounts of betaine, trace amounts of amino acids, trace amounts of vitamin B1.
Dose: 0.5-2.0 l/ha
Application: in autumn: apply at a rate of 0.5-1.0 l/ha at the stage of leaf development when 4-6 leaves are unfolded, in spring: apply from the start of growth period to the stage when plants reach the stage of loose buds.
Effect on the plant: a unique product containing 5% of marine algae extract obtained in the process of cold extraction so that none of the essential ingredients are denatured, intended for foliar application to accelerate growth and increase the resistance of treated plants to stress factors.
BIOFOL BOMBARDINO
Ingredients: organic matter content – 70%, algae concentrate – 35%, organic carbon – 30%, free L-amino acids – 5%, polysaccharides, phosphorus, potassium, magnesium, iron, calcium, copper, vitamins B1, B2, B3, B6, B9.
Dose: 1 l/ha
Application: in autumn: in spring: apply from the start of growth period to the stage when plants reach the stage of loose buds.
Effect on plants: biostimulants and biofertilizer of the latest generation for foliar application on all crops, accelerating plant growth and enhancing resistance to stress factors (e.g. drought), increasing root mass, increasing photosynthesis area, accelerating leaf and stem growth, more intensive carbohydrate production, increased resistance to diseases, accelerating recovery from various types of damage, increasing vigour due to enhanced metabolism and cell division, increasing yield potential and improving yield quality at the same time.
BIOFOL MAG
Ingredients: potassium (K) total – 15.0 g/l, magnesium oxide (MgO) total – 127.0 g/l, nitrogen (N) total – 50.0 g/l.
Dose: 1.5 to 2.5 l/ha
Application: apply twice during the growth period, the first time at the stage of leaf development when 4-8 leaves are unfolded, the second time at the moment of the shoot elongation; the third treatment aims at maximizing yield and quality and should be carried out when the petals start to fall and the dose should be 2.5 l/ha.
Effect on plants: reduces the negative effects of various stress factors (pests, cold, drought, excessive weed infestation), the product is ideal for use in late stages of plant development; it significantly increases the yield and its quality, contains 2.5% of amino acids of plant origin, mainly proline, thiamine, glutamic acid and a surfactant that provides excellent coverage of the treated plant surface, additionally supplements magnesium deficiencies.

TABLE 29. Examples of biostimulants recommended for winter oilseed rape*; cont.

BIOFOL ROOTINO
Ingredients: carboxylic acids 5%, triglyceride 1%, L-amino acids 1%, glucoside surfactant 0.5%, glycine betaine, 4-aminobenzoic acid, vitamin B3, N-Acetyl-p-aminophenol.
Dose: 0.6 l/ha
Application: apply at the stage of leaf development when 3-4 leaves are unfolded until the end of autumn growth period; if two treatments are conducted, the first one should be performed at the stage when 3 leaves are unfolded, and the second one within 10-14 days from the first treatment.
Effect on plants: the product is a new generation root stimulant and biofertilizer, is characterised by a completely different, new formulation and constitutes an alternative to products based on hormones; it is based on specific amino acids and bio-based inducers, stimulates the plant to root, activates the root system and to stimulate the growth of all types of crops (field cultivation, vegetables, orchards, etc.) during the initial stages of the vegetative development cycle.
BIOFOL SUNAGREEN
Ingredients: 2-aminobenzoic acid 5.0 ± 0.5 g/l, 2-hydroxybenzoic acid 2.5 ± 0.5 g/l
Dose: 0.5 l/ha
Application: 1st dose: from rosette formation to the end of intensive growth (BBCH 15-39), II dose: from green to yellow bud stage (BBCH 50-59) preferably on the green bud – extends the flowering period.
Effect on plants: growth stimulant is a combination of organic acids important in the synthesis of active substances responsible for the process of plant growth and chlorophyll formation, increase the positive effect on the metabolism of plants, photosynthesis, respiration and assimilation, manifests itself in more intensive growth of aboveground and – in particular – underground parts of plants.
BIOPOLIN
Ingredients: citral, 2-methoxy-4-(2-propenyl) phenol, 1,2-benzisothiazolin-3-one.
Dose: 0.75-1.0 l/ha using product at 1% concentration (1 l of the preparation in 100 l of water)
Application: from the beginning to full flowering of the oilseed rape (BBCH 61-65)
Effect on plants: preparation for spraying of flowering crop plants used for the purpose of increasing their attractiveness for pollinating insects, mainly honeybees, used in cultivation of vegetables, trees and fruit bushes and oilseed rape; it contains a composition of various substances of natural origin, which, when mixed together, have strong attraction properties for bees and other pollinating insects (e.g. red mason bee, bumblebee). Product advantages: bees and other insects visit flowers of plants treated with the preparation more willingly and frequently, improved pollination of flowers, increase in quality and quantity of the crop.

TABLE 29. Examples of biostimulants recommended for winter oilseed rape*; cont.

BLACK JAK
Ingredients: leonardite min 28%, organic matter content, humins, ulmic acids, humic acids, fulvic acids, other minerals, ph 4.5.
Dose: maximum/recommended application rate for a single use: 2 l/ha in autumn, maximum/recommended application rate for a single use: 1.5 l/ha in spring.
Application timing: at the stage of leaf development when 3-4 leaves are unfolded, in spring: immediately after the start of the growth period; the treatment can be repeated after 2-3 weeks. Number of treatments: 3.
Effect on plants: a product for all agricultural, orchard and vegetable crops, natural and chemically pure; it does not contain any heavy metals or pollutants; the use of the product does not result in phytotoxicity; it strengthens the germination energy, stimulates the production and growth of roots, stimulates seed germination, reduces transplanting stress, helps plants to return to normal growth period after winter, facilitates the uptake of microelements.
ELVITA ALGA
Ingredients: organic carbon 14%, organic nitrogen 2%, organic matter 50%, yeast extract, Ecklonia maxima brown algae extract
Dose: 1.5-2 l/ha
Application: at the stage of leaf development when 2-6 leaves are unfolded, in spring: after the start of the growth period and at the green bud stage. In emergency situations immediately following the occurrence of stress factors.
Effect on plants: initiating increased secretion of endogenous cytokinins, preparing the plant for abundant flowering, improving fertilization and fruit setting, preventing flower and bud fall under unfavourable conditions, more efficient action of nutrients and water uptake from the soil.
ELVITA AMINO
Ingredients: organic nitrogen (N) 8%, organic carbon (C) 23.5%, organic matter 47%, total amino acids 50%, free amino acids 27.5%
Dose: 2-2.5 l/ha
Application: at the stage of leaf development when 4-6 leaves are unfolded, in spring: after the start of the growth period and at the green bud stage. In emergency situations immediately following the occurrence of stress factors.
Effect on plants: fast regeneration of plants after stress, increase of natural resistance of plants to stress, increase in the amount and acceleration of the rate of absorption of foliar fertilizers and agrochemicals, energy saving in the process of protein synthesis, stimulation of accelerated vegetative growth of plants, increase in yield productivity.

TABLE 29. Examples of biostimulants recommended for winter oilseed rape*; cont.

ELVITA AMINOSTIM
Ingredients: product based on amino acids of plant origin
Dose: 1.5-2 l/ha
Application: to be applied when plants are flowering
Effect on plants: influences the overall condition and vigour of the plant, supports the biological and metabolic functions of the plant, influences strong growth, development and yield as it contains plant amino acids; a natural carrier of nutrients, accelerates the rate of their absorption in the crop, supports the plant even under unfavourable conditions.
ELVITA ANTYSTRES
Ingredients: organic nitrogen 4.5%, organic carbon 15%, calcium oxide 5%, molybdenum (Mo) 0.1%, free amino acids 15%
Dose: 1.5-2 in autumn; 1.5-2 in spring
Application: at the stage of leaf development when 2-6 leaves are unfolded, in spring: after the start of the growth period and at the green bud stage. In emergency situations immediately following the occurrence of stress factors.
Effect on plants: leads to stimulation of natural resistance mechanisms against abiotic stresses, prevention of the effects of unforeseen stresses, alleviation of symptoms and acceleration of plant regeneration after the occurrence of stresses, minimization of stress losses, reduction of losses caused by physiological diseases.
ELVITA PROMES
Active substances: total nitrogen (N) – 2%; soluble organic nitrogen (N) – 2%; organic carbon (C) – 14%; organic matter with nominal molecular mass <50 kDa – 50%; yeast extract, Ecklonia maxima brown algae extract
Dose: 1–1.5 l/ha
Application: at the stage of leaf development when 2 - 6 leaves are unfolded, in spring: after the start of the growth period.
Effect on plants: when applied in a foliar application, the product causes in the plant: initiation of increased secretion of endogenous cytokinins, stimulation of growth and development of the root system, improvement of nutrient and water uptake, improvement of the efficiency of co-administered plant protection products, ensures proper plant habit before winter, low setting of the growth cone, thickened root collar, strengthened root system.
ELVITA START
Ingredients: total nitrogen (N): 3%, amide nitrogen ($N\text{-}NH_2$): 3%, water-soluble phosphorus pentoxide (P_2O): 27%, water-soluble magnesium oxide (MgO): 6%, iron (Fe) chelated by EDTA: 0.05%, zinc (Zn) chelated by EDTA: 0.1%
Dose: 1.5-2 l/ha
Application: at the stage of leaf development when 2-4 leaves are unfolded, in spring: after the start of the growth period until the green bud stage.
Effect on plants: application of the fertilizer, especially at low temperatures and in poor sunlight, leads to: accelerated start of growth period, good plant habit through improved rooting, dynamic growth of plant weight.

TABLE 29. Examples of biostimulants recommended for winter oilseed rape*; cont.

FOLIQ AMINOVIGOR
Ingredients: boron (B) – 2.0 g/l; copper (Cu) – 6.0 g/l; iron (Fe) – 24.0 g/l; manganese (Mn) – 6.0 g/l; molybdenum (Mo) – 0.2 g/l; zinc (Zn) – 6.0 g/l.
Dose: 2-3 l/ha
Application: 2-3 treatments: in autumn – one treatment at the stage of leaf development when 8 leaves are unfolded, in spring: 1-2 treatments from the beginning of main shoot elongation to the beginning of flower bud development.
Effect on plants: the fertilizer contains natural, biologically active substances which increase the plants' resistance to abiotic stresses and support the regeneration processes; it is particularly recommended for supporting plants which have been affected by negative environmental factors such as frost, drought, hail, low or high temperatures; it has excellent wetting and adhesion properties and it optimizes the pH of the working liquid, thanks to which it can be used for the purpose of increasing the effectiveness of pesticide treatments. It is suitable for foliar and soil application and via irrigation systems.
FOSFYN
Ingredients: potassium oxide (K_2O) – 185 g/l; copper (Cu) – 6.6 g/l; phosphorus pentoxide (P_2O_5) – 290 g/l
Dose: 1-2 l/ha
Application: at the stage of leaf development when 4-8 leaves are unfolded, in spring: after the start of the growth period until the green bud stage, beginning of lateral shoot development – 6 visible internodes.
Effect on plants: stimulation of natural plant immunity and supply of nutrients, increased plant tolerance to unfavourable growing conditions, effective supply of phosphorus and potassium to plants.
AMINOPLANT
Ingredients: total nitrogen (N) content at least 9.1% (m/m); organic nitrogen (Norg) content at least 8.7% (m/m); ammoniacal nitrogen (N-NH4) content at least 0.4% (m/m); free amino acid (FAAS) content at least 10.0% (m/m); organic carbon (Corg) content at least 24.0% (m/m); organic matter content at least 63.0% (dry mass)
Dose: 1-1.5 l/ha
Application: 1-2 treatments per season, the first treatment should be carried out before flowering, the second 10-14 days later
Effect on plants: improvement of yield uniformity under unfavourable conditions, e.g. insufficient humidity, too low or too high temperatures, decrease in nitrate content due to improved nitrogen metabolism resulting from the increased activity of enzymes responsible for the uptake and further metabolism of nitrogen in cells.

TABLE 29. Examples of biostimulants recommended for winter oilseed rape*; cont.

GOEMAR MULTOLEO
Ingredients: water-soluble boron (B) – 9.9%; contains biologically active GA 142 filtrate obtained from theAscophyllum nodosum algae.
Dose: 1-2 l/ha
Application: 1 spraying from the start of growth of the main shoot to the end of budding.
Effect on the plant: increases flowering intensity and improves the setting of pods in oilseed rape cultivation, thus increasing yield.
GROWON
Ingredients: total nitrogen (N) – 70 g/l; urea nitrogen (N) – 70 g/l; phosphorus pentoxide – 500 g/l; boron (B) – 1.4 g/l; zinc (Zn) – 1.4 g/l.
Dose: 1-4 l/ha
Application: from emergence to early flowering (BBCH 13-61)
Effect on plants: activator intended for foliar application, used for the purpose of ensuring the fastest supply of plants with phosphorus, an element that is needed for production of energy necessary for proper growth and development, indispensable in conditions when the uptake of phosphorus by plants is insufficient, stimulates root and yield-forming organ growth, especially under conditions of low soil and air temperature and on acid and alkaline soils, increases the tolerance of plants to cold, improves the yield and its quality.
IMPROVER+
Ingredients: potassium 4-nitrophenolate (potassium para-nitrophenolate), potassium 2-nitrophenolate (potassium ortho-nitrophenolate), potassium 5-nitroguaiacolate (potassium 2-methoxy-5-nitrophenolate)
Dose: 0.5-1.0 l/ha
Application: in oilseed rape from the stage of leaf development when 4 leaves are unfolded to budding. Treatment can be repeated up to 3-4 times during the growing season, at 2-4 week intervals.
Effect on plants: The product is particularly useful in periods when plants are subjected to stress factors, for the regeneration of damaged tissues and when we need to accelerate vegetative and generative growth.
KAISHI
Ingredients: free L-amino acids of vegetable origin (% W/W – 12.0, % W/V – 13.0) nitrogen (n) (% W/W – 2.0, % W/V - 2.1)
Dose: 1.5–2.0 l/ha
Application: after the spring start of growth period, in the budding stage until the beginning of flowering, in the full flowering stage until the beginning of pod setting.
Effect on plants: free L-amino acids stimulate metabolic processes in the plant, disturbed as a result of the plant being subjected to stress factors, the plants become more tolerant to stress factors and recover faster after their occurrence because L-amino acids extert a positive impact on photosynthesis, cell wall strengthening and stomata work; in addition, some amino acids (L-proline, L-methionine, L-tryptophan) improve plants' health and have a positive effect on their development as they are precursors of phytohormones and growth substances.

TABLE 29. Examples of biostimulants recommended for winter oilseed rape*; cont.

KELPAK
Ingredients: auxins – 11 mg/l, cytokinins, alginates, brassinosteroids, gibberellins, phlorotannins (Eckol), polyamines, liquid algae concentrate Ecklonia maxima
Dose: 2 l/ha
Application: in autumn, at the stage of leaf development when 3-5 leaves are unfolded and again in the spring after the start of growth period (rosette stage until the beginning of stem elongation).
Effect on plants: intensifies the growth of lateral roots, which in turn improves plant nutrition, facilitates water uptake and vegetative development, enhances flowering and pollination processes, accelerates pollen tube growth, alleviates the effect of biotic and abiotic stresses and reduces transplant shock, influences the size, colour and sugar content of fruit and vegetables, improves shelf life of fruit and vegetables, increases profit thanks to better yields.
NATURAMIN PLUS
Ingredients: free amino acids – 40.0%; total nitrogen (N) – 7.50%; water-soluble iron (Fe) – 1.25%; water-soluble manganese (Mn) – 40.0%; water-soluble boron (B) – 0.12%; water-soluble molybdenum (Mo) – 0.058%; water-soluble copper (Cu) – 0.12%; water-soluble zinc (Zn) – 0.25%
Dose: 1-1.5 l/ha
Application: at the stage of leaf development when 4-6 leaves are unfolded
Effect on plants: inhibits the adverse effects of: diseases, pests, improper soil preparation, drought, soaking, too low/high temperature or exposure to excessive sunlight; L-proline and glutamic acid supports the process of pollination, and valine, isoleucine, leucine – processes of ripening, prevents dwarfing and low productivity of plants, amino acids in the support the formation of enzymes and protein synthesis necessary for proper physiological functioning and development of plants.
OPTYCAL
Ingredients: calcium oxide (CaO) – 350 g/kg; formate – 560 g/kg; copper (cu) – 0.5 g/kg; iron (Fe) – 1.5 g/kg; manganese (Mn) – 0.7 g/kg; boron (B) – 1.0 g/kg; molybdenum (Mo) – 0.02 g/kg; zinc (Zn) – 2.0 g/kg
Dose: 1.5 kg/ha
Application: in autumn at the stage of leaf development when 4-8 leaves are unfolded; in spring: beginning of main shoot growth
Effect on plants: stimulates the uptake of calcium from soil and its transport to the youngest parts of plants (calcium-auxin pump effect), supplies easily absorbable organic calcium directly through foliar application.

TABLE 29. Examples of biostimulants recommended for winter oilseed rape*; cont.

OPTYSIL
Ingredients: silicon (SiO_2) - 200 g/l
Dose: 0.5 l/ha
Application: at the stage of leaf development when 4–8 leaves are unfolded, in spring: beginning of main shoot growth; compact green flower bud; loose green bud – to the beginning of flowering; from the beginning of petal falling – to the beginning of pod development.
Effect on plants: higher plant tolerance to unfavourable growing conditions (e.g. drought), reduced impact of biotic stress caused by pathogens and/or pests, stimulation of root growth in young plants, better yield, higher quality and improved storability of the crop.
POLLINUS
Ingredients: allelochemicals (geraniol, citral, anethole, linalool) – 500 g/l
Dose: 1 l/ha
Application: to be applied during flowering, the best results are obtained by carrying out two spraying treatments – the first spraying on the plantation is recommended at the beginning of flowering (about 10% of flowers are open), the second treatment should be carried out in full bloom, when about 90% of flowers are open. It is also possible to perform one treatment when the plantation is in full bloom (about 80% of flowers are open).
Effect on plants: an increase in the number of bees and other pollinating insects in the field and improvement of their work efficiency, improved pollination of flowers – leading to an increased number of seeds in the fruit; a larger number of seeds affects the intensity of transport of nutrients to the growing buds; improvement in the quality of fruit (they are more shapely, have a higher taste, are less susceptible to physiological diseases – their storability is improved) and an increase in fruit yield.
ROOTER
Ingredients: water-soluble phosphorus pentoxide (P205) – 13.0%; water-soluble potassium oxide (K2O) – 5.0%, biologically active GA 142 filtrate obtained from the Ascophyllum nodosum algae.
Dose: 1-2 l/ha
Application: in autumn (at the stage of leaf development when 4-6 leaves are unfolded), in the spring after the start of growth period.
Effect on plants: improves pod setting in oilseed rape and in legumes, improves the development of the root system and accelerates its regeneration as well as enhances the uptake of mineral nutrients from soil, improves plant growth at the initial stage of cultivation and maintains high vigour of the plant during further growth period, which translates into increased yield.

TABLE 29. Examples of biostimulants recommended for winter oilseed rape*; cont.

ROOTSTAR
Ingredients: ammonium nitrogen (N) (NH4) - 17 g/l, zinc (Zn) - 67 g/l
Dose: 0.8-1.2 l/ha
Application: after plant emergence (BBCH 10-14); in spring: after start of growth period
Effect on plants: dynamic development of root mass, improvement of plant health in the early stages of development, increased tolerance of plants to stress factors such as low soil temperature and water deficiency.
SHIGEKI
Ingredients: ascophyllum nodosum algae extract (% W/W – 10.0, % W/V – 10.5), boron (B) (% W/W – 0.10, % W/V – 0.11), molybdenum (Mo) (% W/W – 0.05, % W/V – 0.06), copper (EDTA Cu) (% W/W – 0.05, % W/V – 0.06), iron (EDTA Fe) (% W/W – 0.10, % W/V – 0.11), manganese (EDTA Mn) (% W/W – 0.10, % W/V – 0.11), zinc (EDTA Zn) (% W/W – 0.10, % W/V – 0.11)
Dose: 2.0-4.0 l/ha
Application: in autumn, at the stage of leaf development when 4-6 leaves are unfolded, in spring: when the growth period until the beginning of pod setting.
Effect on plants: local increase in hormone levels, which stimulates plant metabolism and nutrient uptake.
TYTANIT
Ingredients: Titanium (Ti) - 8.5 g/l
Dose: 0.2–0.4 l/ha
Application: at the stage of leaf development when 4–8 leaves are unfolded, in spring: beginning of main shoot growth; compact green flower bud; loose green bud – to the beginning of flowering; from the beginning of petal falling – to the beginning of pod development.
Effect on plants: activation and strengthening of natural physiological processes in plants, favourable influence on quantitative and qualitative yield parameters, plants better supplied with water and nutrients, healthier plants more tolerant to adverse growing conditions.
VITAMIX
Ingredients: potassium (K2O) total 215.0 g/l; phosphorus (P2O5) total 250.0 g/l; copper, manganese, zinc, iron, molybdenum, boron; contains humic and fulvic acids of natural origin
Dose: 0.5-2.0 l/ha
Application: in autumn: use 0.5 l/ha at the stage of leaf development when 3 leaves are unfolded; in spring: from the start of growth period to flowering
Action on the plant: compensates for potassium and phosphorus deficiencies in critical periods, especially in plants strongly responsive to deficiencies of these nutrients, accelerates root development in the initial stages of plant development, increases resistance of treated plants to stress, including stress caused by some pathogens; increases assimilability of nutrients and enhancing their movement in the treated plants.

*Based on labels

VI.3. AGROTECHNOLOGY AND PLANT GROWTH AND DEVELOPMENT REGULATORS AND BIOSTIMULANTS

The influence of agrotechnology on growth regulation as well as growth stimulation of winter oilseed rape is mainly connected to two aspects. The first is related to the choice of variety, and the second to sowing.

PLANT HEIGHT AND VARIETY

The regulation of winter oilseed rape height by the specific properties of varieties is related to the cultivation of lower varieties and those less prone to lodging. When choosing a variety to cultivate, read its characteristics and sow the one that is recommended for the site, lower and less prone to lodging. This will make it possible to dispense with the use of preparations that directly or indirectly regulate plant height. In addition, by selecting the right variety for the site, the oilseed rape will be in good condition, which makes it possible to dispense with the application of biostimulants.

SEMI-DWARF AND DWARF VARIETIES

Nowadays, an increasingly larger area is devoted to the cultivation of semi-dwarf and dwarf varieties. In favour of growing these varieties is the fact that semi-dwarf and dwarf varieties are considerably lower than traditionally grown varieties, both open-pollinated and hybrids. Semi-dwarf varieties are assumed to be at least 50 cm lower than traditional population varieties. In the case of dwarf varieties, the reduction in growth is even greater.

FOR WEAKER SITES

When deciding to limit the height of plants by growing semi-dwarf and dwarf varieties, one must remember that they are most often grown on lighter soils, less rich in nutrients. Semi-dwarf and dwarf varieties of winter oilseed rape do well on such sites. These plants, due to smaller aboveground mass, are less prone to lodging and have lower demand for water and nutrients dissolved in it.

WITHOUT GROWTH REGULATOR

The morphological structure of semi-dwarf and dwarf varieties differs from traditional open-pollinated and hybrid varieties. Differences can be seen right from the start of the growing season. In autumn, semi-dwarf and dwarf varieties build a compact, low-set rosette.

In this period, the root collar is very close to the ground, which, in addition to not having to adjust the height, has a beneficial effect on the overwintering of oilseed rape. Therefore, fungicide protection should be approached differently. In case of semi-dwarf and dwarf crops preparations that are based on growth regulators should be abandoned.

SOWING IN HEIGHT ADJUSTMENT

SOWING DATE

The sowing date of winter oilseed rape is another element that can be used to adjust the height to some extent. When deciding to regulate the height of oilseed rape using the sowing date, it should be remembered that oilseed rape is classified as a crop sensitive to the sowing date.

Therefore, when deciding to adjust the height in the initial period of its growth and development using the sowing date, it is necessary to base this decision on the experience. It should be remembered that dynamic growth and development of winter oilseed rape takes place only at average ambient temperatures above 12°C.

LATE SOWING AND PLANT GROWTH

Due to varying weather conditions in different regions of the country, oilseed rape is sown at different dates. In the northeast part of the country, winter oilseed rape sowing should be finished in the first ten days of August (by 10th of August). In the rest of the country, oilseed rape sowing should be carried out between 15th and 25th of August. In the eastern part of the Mazowieckie Voivodeship and the Warmińsko-Mazurskie Voivodeship, sowing should be done by 15th of August. Slightly later, by 20th of August, oilseed rape should be sown in Pomorskie Voivodeship, Kujawsko-Pomorskie Voivodeship, the rest of Mazowieckie Voivodeship and the eastern part of Podkarpackie and Świętokrzyskie Voivodeship. In the rest of the country, the sowing should be carried out by 25th of August. It is permissible to delay sowing of oilseed rape by 5–7 days. Plants from later sowing are smaller. Under favourable weather conditions they are able to produce an adequate rosette, as well as the root system necessary for safe overwintering. In order for oilseed rape to overwinter well, it should form a rosette of 8–9 leaves (in accordance with the BBCH-scale: 18–9) before stopping growing in autumn. The root, on the other hand, should have a diameter of more than 1 cm. Delays longer than 5–7 days are not advisable, because they carry the risk that the plants do not "prepare" properly for winter rest.

EARLY SOWING AND PLANT GROWTH

The sowing date can also stimulate oilseed rape growth. Early sowing makes the plants larger and produce more leaves, and the root is larger in diameter. In this case the experience is the most important factor as well. Please note that if oilseed rape is sown too early it can overgrow and even cause plants to rank. This situation occurs in the high temperatures of late summer. Growth stimulation of oilseed rape by earlier sowing is allowed only when weather conditions are not conducive to rapid growth, and when oilseed rape is grown on weaker soils and after a cereal preceding crop. When deciding on early sowing, it is important to remember that it should not be done earlier than 5-7 days prior to the designated end date in the given region.

SOWING TECHNIQUE AND PLANT GROWTH

At present, it is common in Polish agriculture to sow oilseed rape using row seed drills. However, this trend is changing in favour of precision sowing, which is done with a precision drill. This solution is quite beneficial. Firstly, much less seed is needed for precision sowing than for traditional row sowing. Secondly, the precise distribution of plants per unit area favourably influences plant health as well as oilseed rape traits that affect yield and its quality parameters (Table 30). By analysing the effect of sowing technology on the height of plants it can be unequivocally stated that plants from precision sowing are 20 cm taller in comparison to those that were sowed traditionally. Sowing technique not only affects the height of the plants, but also the other characteristics of oilseed rape. By precision sowing of oilseed rape it is possible to stimulate parameters affecting yield and quality without using preparations to stimulate plant growth. Precision sowing can be successfully used to grow traditional as well as semi-dwarf and dwarf varieties.

TABLE 30. Influence of sowing technology on selected features of winter oilseed rape, with particular emphasis on plant height

Feature	Row sowing, row spacing – 33 cm	Precision sowing, row spacing – 45 cm
Planting density before harvest (pcs./m^2)	36.4	27.1
Pre-harvest root collar thickness (mm)	18.0	24.3
Height of the crops (cm)	**170**	**190**
Number of lateral branches (pcs/plant)	6.3	8.5
Number of lateral branches (pcs/m^2)	229.3	230.4
Number of pods (pcs./m^2)	10,190	11,650
Seed yield (t/ha)	5.2	5.6

Source: Piskier T., Deresz E. 2016. Rzepak w siewie punktowym. Bez Pługa 1: 30-31.

VII OILSEED RAPE PRODUCTION TECHNOLOGIES AND THE BALANCE OF BENEFICIAL ORGANISMS WITH PARTICULAR EMPHASIS ON POLLINATORS

VII.I. IMPACT OF OILSEED RAPE CULTIVATION ON BIODIVERSITY, INCLUDING THE PRESENCE OF POLLINATING INSECTS

Oilseed rape cultivation technologies, just like production processes of all other agricultural crops, largely disturb the biodiversity of the environment.

In relation to natural ecosystems, agricultural crops are in principle artificial ecosystems, much less rich in terms of occurrence of both species of organisms and the relations between them. Oilseed rape fields are just such artificial ecosystems, simplified to the maximum extent, with the main growing period in spring and early summer. There is no doubt about the fact that it is impossible to obtain high and healthy oilseed rape yields are without implementing the necessary agricultural practices and using chemical protection against agrophages. Unfortunately, achieving high production while maintaining high levels of biodiversity, is impossible on a single field. Oilseed rape, as it is widely known, requires effective herbicide, fungicide and insecticide protection throughout the growing season. However, the biodiversity limitation of agricultural crops can be modified to a certain extent by selecting such production technologies that minimize the impact on biodiversity and possible negative consequences of its limiting. In the case of oilseed rape crops, this is particularly important in the context of beneficial entomofauna, especially pollinating insects.

BIODIVERSITY OF OILSEED RAPE CULTIVATIONS

Oilseed rape fields serve as a home to many insect species, some of which are treated as pests, i.e. species that cause losses that exceed the cost of controlling them. From the point of view of plant protection and implementation of biological method of plant protection, beneficial entomofauna is of fundamental importance in regulating the population of insects, including harmful insects, and it should constitute a very important element of integrated crop protection against pests.

At the flowering stage (BBCH 57-72) and later on, oilseed rape crops are a habitat for many species of these animals, among which the honeybee is particularly important. However, one should not forget that in addition to the honey bee, which is the main pollinator of oilseed rape, fields of flowering oilseed rape are also pollinated by representatives of *Hymenoptera, Lepidoptera, Diptera, Coleoptera* and many other orders of insects. They belong to the category of primary consumers, feeding on pollen and nectar of flowers, and their function in the process of pollination of oilseed rape flowers is (like in the case of the honey bee) very important.

Besides the beneficial pollinators, oilseed rape crops are also infested with predatory and parasitic insects, mainly *Heteroptera, Diptera, Hymenoptera, Coleoptera* and other orders of insects; thus, oilseed rape fields constitute an important element of the so-called "environmental resistance" to pests. One of the most important groups that populate agroecosystems are beetles; these non-specialised predators play an important role as natural enemies of plant pests. Ladybirds *Coccinellidae* contribute substantially to the regulation of phytophagous populations occurring on plants (including oilseed rape) and are significant from the economic point of view. There are 3500 described species of ladybirds in the world; in Poland there are more than 70 species. Beneficial beetles of the *Coccinellidae* family are natural enemies of scale insects, whiteflies and mites. These insects are important regulators of aphid population in agrocenoses. A number of factors can influence the dynamics of *Coccinellidae* population, synchronisation of the predator-prey relations being one of the most important ones. An increase in ladybird populations occurs analogically to the increasing populations of aphids feeding on plants. No ladybird species is threatened by natural factors such as other predators due to the high reproductive capacity of *Coccinellidae*. However, the population of this species in the wild and its distribution is dramatically declining due to environmental pollution and widespread use of pesticides. The most common ladybugs in Poland are *Coccinella septempunctata, Adalia bipunctata, Propylea quatuordecimpunctata, Stethorus punctillum* and, recently, *Harmonia axyridis*. During its development the ladybird larva can destroy up to two thousand aphids. Adult insects eat from 30 to as many as 250 aphids per day. Some species, e.g. *Adalia bipunctata*, are used in agriculture as a biological means of controlling aphid population. A large group are predatory insects of the ground beetle *Carabida*e family. Because *zoophagous Carabidae* play a major role in limiting the populations of phytophagous, these species have been granted partial legal protection. Winter oilseed rape plantations are an excellent place for these beetles to thrive. After the sowing carried out in autumn, they colonise the plantation; later on, in spring, a very large spring generation appears and helps to protect the crops. In Poland the ground beetle family belongs taxonomically to one of the largest groups of insects, comprising of more than 500 species of beetles. Most of them have a terrestrial lifestyle – on the surface and in the top organic layers of the soil, where they forage, breed and overwinter. Aphids, caterpillars of butterflies, e.g. the caterpillars of black cutworm, or larvae, immobile chrysalises, and earthworms are the prey of the ground beetle. Also, beetles of the *Staphylinidae* family belong into the category of the pest-reducing insects. It is the largest insect family in Poland, consisting of over 1400 species.

Important predatory insects are some *Diptera*, mainly those belonging to the *Syrphidae* and *Tachinidae* families. Larvae of hoverflies belong to the most important natural enemies of aphids. Therefore, *Syrphidae* are a potential source of afidophages for related agrocenoses. Hoverflies produce several generations per season, which accounts for their high effectiveness as predators. The larvae are most effective when aphids feeding on oilseed rape plantations appear on a massive scale. This is due to the fact that *Syrphidae* larvae are not very mobile and "blindly" search for their prey, hence the density of aphid colonies has a significant impact on the effectiveness of these predators. As a rule, female *Syrphidae* lay their eggs in the vicinity of aphid colonies. Most females when they lay their eggs choose plants that are highly colonized by these pests. The larvae only partially suck out the contents of the aphid's body, which increases the number of infested individuals. During larval development, 1 individual destroys between 200 and 1000 aphids. As far as *Heteroptera* group is concerned, predators from the *Miridae, Anthocoridae* and *Pentatomidae* families contribute significantly to pest management. In particular, the common flowerbug *Anthocoris nemorum* plays an important role in reducing aphids and red spider mites (eggs and larvae), and young caterpillars. Both larvae and adults of *Heteroptera* suck the bodily fluids from captured insects.

Hymenoptera also reduce the population of plant pests. These are mainly the predatory *Formicidae* and the parasitic *Ichneumonidae*. For these insects oilseed rape fields are as a great place for food foraging. Ants feed on representatives of 150 species of invertebrates from 58 families and 21 orders. Flies, beetles, butterfly caterpillars and plantar larvae predominate in this group. Ants fall into the category of the most important predators inhabiting stable environments. These insects, in addition to their primary role as regulators of pest populations, participate in initiating soil processes and interact with other groups of organisms (microorganisms). Another group of beneficial insects are the *Dermaptera*, commonly called earwigs or pincher bugs due to their pincers, which they use for defensive purposes, to ward off attackers; they are also helpful during copulation. Earwigs are predatory insects which have a nocturnal lifestyle, their prey on aphids and other small insects.

As non-specialized predators the *Araneae* reduce the number of pests in fields and constitute a permanent element of agrocenoses. Due to their high abundance and sensitivity to changes of various factors, they are an interesting subjects for environmental studies. About eight hundred species of these animals live in Poland. They feed on insects, therefore they inhabit the same environments. Many spiders create vertical or horizontal webs by means of which they catch their prey, but others prefer to hunt actively, searching for prey or attacking them by surprise. Spiders are not well-liked animals and evoke fear in many people. Despite this, they are very useful creatures because they reduce the number of insects, including those that are parasitic and cause damage. Their beneficial activities are manifested both in the natural environment and in our own homes, which are inhabited by many synanthropic species. We should remember about this positive role of spiders in our lives.

The biodiversity of oilseed rape fields is also affected by a large group of animals and other saprophagous organisms feeding on dead organic matter, whose role in the matter cycle is particularly important, especially within the scope of increasing the soil fertility and capability for succeeding plants. In the light of the above, all actions aimed at limiting treatments that negatively influence biodiversity, including mainly chemical treatments, should always be taken into consideration by farmers.

IMPACT OF OILSEED RAPE CULTIVATION

In addition to well thought-out chemical protection, which has a direct impact on the oilseed rape field ecosystem, other measures not directly related to oilseed rape cultivation are also very important. Being aware of the importance of biodiversity of fauna and flora in the agricultural landscape and individual decisions made by farmers can significantly reduce the negative effects of modern agriculture. There is a very wide range of possibilities for indirect impacts on the biodiversity of agricultural crops, including oilseed rape. The biodiversity of all groups of invertebrates is positively influenced by crop rotation, but negatively influenced by monoculture systems, which mainly generate herbivorous species such as nematodes. Research on the effects of particular cultivation systems (conventional, no plough tillage, direct sowing) on soil invertebrate fauna is currently being conducted. It is also important to increase small water retention, soil retention, shaping the structure of plant cover around fields, and increasing the complexity of agricultural landscape by creating ecological passageways for many animal species.

While striving for the preservation of biodiversity, one should not forget about the need to preserve relict ecosystems (peat bogs, marshes, wet meadows, etc.), ecotone zones on the border between forest and field, baulks, farmland woodlots, thickets along watercourses, ponds, rushes, etc. A good example here are the mid-field afforestations established near Turew in Wielkopolskie voivodeship by Gen. D. Chłapowski back in the 19th century. They were supposed to prevent wind erosion and soil drying, but are now also being evaluated for their effects on pests and their natural enemies. These actions, consisting particularly in creating conditions for the residence, feeding and overwintering of beneficial species, are essential for crop protection. Increasingly, the so-called refugia are being established in agricultural crops, where species that produce large amounts of nectar and pollen are sown alongside the main crop. In these places, beneficial insects or arthropods thrive and from here they invade the fields, reducing pest populations and keeping them at a safe level for the crop. Wild plants located near cultivated fields and mid-field woodlots perform a similar function. They are a source of food for beneficial organisms, provide shelter and a place to overwinter, allowing them to grow safely.

There is a possibility of co-financing any agri-environmental and climatic actions aimed at enriching biodiversity; detailed information can be found on the website of the Agency for Restructuring and Modernisation of Agriculture. Preservation of biodiversity is an overriding objective of action resulting not only from the implementation of international provisions, but also – and perhaps above all – from understanding that this is the only way to preserve safe functioning of life on earth. It is also a means of increasing the share of biological plant protection methods usage in crop protection against pests.

VII.2. THE IMPORTANCE OF OILSEED RAPE CULTIVATION FOR HONEYBEES AND APIARY MANAGEMENT

As it was proven by many scientific experiments on the role of bees and other insects in the cross-pollination of oilseed rape plants, it is known that these plants respond to insect pollination with a significant yield increase. Depending on the variety, thanks to the phenomenon of heterosis (i.e. outbreeding enhancement), it ranges from approximately 10 to over 30%. In the case of hybrid oilseed rape varieties, their yield-forming potential very much depends on pollination by insects. The profitability of their cultivation is therefore determined by the pollinating insects, with the dominant role of the honeybee. Every oilseed rape grower should make sure that during flowering as many of these insects as possible pollinate their plantation. It is recommended that there should be 2-4 bee colonies per hectare of oilseed rape. It is also very important and profitable for the beekeeping industry to give the bees the best possible access to flowering oilseed rape, which is not only the most important agricultural oilseed crop in Poland but also a melliferous plant. Depending on the variety of this plant, bees from 1 hectare of oilseed rape can produce 80-140 kilograms of nectar oilseed rape honey.

Oilseed rape blooms in late April and early May for an average of three weeks, although this period can fluctuate, depending on the weather patterns. With unfavourable cool weather, the flowering stage can extend up to 37 days. Oilseed rape flowers bloom chronologically, starting from the lower to the upper parts of the cluster. Individual flowers are open for three days from early morning to late afternoon; at night they are closed. Oilseed rape plants may be self-pollinated or facultatively open-pollinated. The flowers, gathered in elongated clusters, exhibit a number of evolutionary adaptations that support cross-pollination, mainly through insect-pollination. It is also possible for pollen to be carried short distances by strong winds. One of the adaptations for cross-pollination is that the pistils mature faster than the stamens in individual flowers, as well as secreting nectar that is attractive to insects and attracting them with the intense yellow colour of the petals and with fragrant substances. A single oilseed rape flower produces about 0.2-2 mg of nectar per day, which, assuming that on average 10-15 thousand flowers bloom on a square metre, gives insects large amounts of this substance. Flowers produce the largest amounts of nectar in the mornings. The sugar concentration in nectar ranges from 25% to 45%; in some varieties it is as high as 60% and increases as the day progresses. After the visit of the pollinating insect – bees after only 30 minutes, the nectaries are filled with a new dose of nectar. Pollen production is also a lure for bees, as it is an important source of high-protein food for these insects. Oilseed rape pollen is heavy and sticky, making it easy to adhere to all parts of insects' bodies, especially the heavily hairy bees. Maximum pollen production by blooming flowers occurs at 9 and 12 am and 3 and 4 pm, which correlates with the highest bee activity. When the weather is favourable and the population of bees is high, each flowering oilseed rape flower is visited by insects every 2-3 minutes, and a single bee visits an average of 7-10 flowers in one minute.

Oilseed rape honey is known for its health-promoting properties. It consists of about 80% of a mixture of glucose and fructose – very easily digestible carbohydrates.

A characteristic feature of oilseed rape honey is the low ratio of fructose to glucose (F/G below 1, i.e. there is more glucose than fructose. Because of that this honey crystallizes very quickly).The remaining 20% is water, trace amounts of protein, organic acids (malic, lactic, citric, butyric, acetic, gluconic), minerals (potassium, cobalt, iron, calcium, sodium, manganese, phosphorus, copper), vitamins (C, PP, B vitamins), essential oils and enzymes.

VII.3. PROTECTION OF OILSEED RAPE AND BIODIVERSITY

Although the honeybee constitutes 75-90% of the entomofauna of pollinators that can be found on Polish fields, we should keep in mind that other species of the bee family (over 460 species in Poland) also play an important role. These include wild bees, i.a. bumblebees (31 species in Poland), as well as numerous species of Hymenoptera, butterflies, flies, beetles and other plant pollinator species. Pollinating insects of different species can be found at different times of day or night, with different temperatures and humidity, from early spring to early winter. All these beneficial animals, as a result of unfavourable environmental changes and the use of contemporary intensive agricultural production technologies, are often exposed to the danger of poisoning or death. They are particularly threatened by plant protection products, mainly insecticides. Protection of beneficial entomofauna is therefore particularly important today. Unfortunately, apart from fairly extensive information on the honeybee, which is the model species studied by natural scientists, knowledge of other insect species is still inadequate. However, one thing has been established with certainty – the rapid extinction of insects over several decades and a drastic decline in the biodiversity of the agricultural environment.

As for the honeybee, examination of its genome revealed that this species has developed a very high diversity of olfactory receptors encoded by approximately 100 genes. This is explained by the coevolution of angiospermae and bees and the social mode of life of this insect, where communication between individuals is based mainly on the secretion and detection of chemical substances. The bee's taste receptors, on the other hand, are encoded by only 10 genes, indicating the minor role of taste in the food it feeds on. The bee has also not evolved a broader ability to distinguish and detoxify plant secondary metabolites because it has not encountered them in pollen or nectar during evolution. Secondary metabolites are most often toxins that protect plants from herbivores; many species of herbivorous insects have evolved enzyme systems capable of detoxifying plant poisons. The genetically determined traits of the honeybee, as confirmed by research, which indicate a low capacity to detoxify poisons, are a sign of a high risk for this species from chemical plant protection products.

As the honeybee has a well-developed brain, the neurotoxins used in insecticides are particularly dangerous to this species. These threats may include contact or oral poisoning, leading to a variety of behavioral changes, memory and navigation disruptions, and even death of the insect. Even minimal amounts of active substances contained in plant protection products brought with concentrated food into the hive can impair the development of a bee colony.

The research conducted by the Institute of Plant Protection – National Research Institute in Poznań has investigated the special role of the protection of beneficial insects, mainly honey bees. These are open field tests or tests conducted in special insulators and laboratories.

These studies analyse many aspects of the use of chemical plant protection products, mainly insecticides and their effect on the risk of bee poisoning, bee behaviour and development.

The aim is to understand both the early and subsequent effects of possible contact of insects with toxins or their metabolites, the ability of insects to detoxify them, and the mechanisms of resistance. The results of many years of research are used in agricultural practice to precisely establish recommendations for the use of plant protection products, in order to minimise their negative effects on honeybees and other pollinator species.

As far as oilseed rape cultivation is concerned, mistakes often lead to poisoning of bees and other beneficial insect species. The programme for winter oilseed rape protection based on registered pesticides is developed and available on the Signalling of Agrophages Platform and on the website of Institute of Plant Protection – National Research Institute in Poznań. Data obtained from product labels which is available from the above-mentioned sources is in accordance with the EU law and is updated twice a year due to changes in the Register of Plant Protection Products. Thanks to this, agricultural producers have continuous access to information on all, including the most recently launched, plant protection products used in oilseed rape cultivation.

BASIC PRINCIPLES OF PROTECTION OF BENEFICIAL ENTOMOFAUNA IN OILSEED RAPE CROPS

1. One of the main principles of the safe use of plant protection products is consists in the user being acquainted with the information on the label as well as with the instructions for use. However, label claims concerning honeybees and other pollinator species are often vague.

For example, the labels of many plant protection products provide no information on bee protection, except for the following statement: "During flowering of crops, it is recommended to apply the product outside periods of activity of bees and other pollinating insects." This should be understood as a statement that the application of the product "does not pose a threat to bees"; however, this declaration is in conflict with the statement that the product is dangerous for bees and should be applied after their flight. In many cases plant protection products labels also contain the warning: "Dangerous to bees" or "To protect bees and other pollinating insects do not apply to plants covered with honeydew". "On crops of flowering plants and where flowering weeds are present, apply the product in the evening, after bees and other pollinating species have completed their flight of the plants." In the light of the current knowledge, such provisions prove to be inadequate, as many species of pollinating insects, such as butterflies, fly over flowering plants at night precisely. Besides, the evening is a very short part of the day – between sunset and night, when the sun is below the horizon line – which means that the farmer has only an hour or so to carry out a chemical treatment.

Many insecticide labels also recommend observation of a precautionary period, i.e. the time that must pass between the application of the product and the time when people can enter the treated area and animals, including breeding insects, can be introduced:

"Do not enter until the spray has completely dried on the plant surface." Every user of a plant protection product should take this warning into account. For example, when spraying oilseed rape or any other crop that provides food for pollinators in May, June or July, it should be taken into account that honeybees and other diurnal pollinators may appear in the plantation already within one hour after sunrise, i.e. around 5-6 am. Unfortunately it is often the case that large fields farmers finish spraying much later than they should, not only in June when the sun sets late (around 20.40-21.00). The working liquid will certainly not dry within 1-2 hours and if bees and other species have a contact with an insecticide that is toxic to them, they might get poisoned or die. Farmers must remember that in case the bees are poisoned, ending the treatment too late will be an important argument should the beekeepers claim damages.

2. In case of any doubts as to the possibility of safe use of the plant protection product, contact a representative of the State Plant Health and Seed Inspection, an Agricultural Advisory Centre or a representative of a scientific institution dealing with plant protection.

3. The preparation of mixtures of active substances of plant protection products as well as the addition of adjuvants and foliar fertilisers to the working liquid may only take place if the plant protection product label allows for such actions. One must remember that in some cases synergism of the active substances may occur and change the product's toxicity to honeybees and other insects.

4. During the flowering period of winter and spring oilseed rape, mustard and other plants that are a source of food for pollinating insects, use insecticides safe for honeybees that do not require the observation of a precautionary period.

5. As a rule, irrespective of the time of year, treatment with a plant protection product on crops where bees may be present should be carried out in the evening, after their flight, and should end 4-5 hours before their possible arrival at the protected plantation.

6. Take into account the possibility of refraining from conducting treatments if the population of pests is low and is accompanied by the appearance of beneficial species. In this group of activities, the treatment area should be limited to border treatments, or spot treatments if the pest is not present in the whole plantation. Recommend the use of tested mixtures of crop protection products and liquid fertilizers, which reduces the number of times when the field needs to be entered as well as mechanical damage to plants.

7. It is essential to keep records of plant protection treatments carried out.

Legal protection measures also constitute an important element of modern protection of plants subjected to chemical treatments. The most important EU plant protection acts and regulations include: Regulation of the European Parliament and of the Council (EC) 1107/2009 – Article 55 of the Regulation imposes an obligation to carry out plant protection in accordance with the principles of integrated pest management, and Directive 2009/128/EC of the European Parliament and of the Council, which in Annex III sets out the general requirements for integrated pest management. In Poland, however, the basic legal act is the Act on plant protection products and the accompanying regulations and legal acts, including the Regulation of the Ministry of Agriculture and Rural Development on the requirements for integrated pest management. The aforementioned Regulation of the Ministry of Agriculture and Rural Development and Annex III to the Directive 2009/128/EC state that: integrated pest management includes "protection of beneficial organisms and establishment of conditions favourable to their occurrence, especially it concerns pollinating insects and natural enemies of harmful organisms". In view of the obligation to protect cultivation in accordance with the principles of integrated pest management, this provision already forms the basis of the obligation not only to protect beneficial organisms but also to create favourable conditions for their development. In addition, the Regulation clearly specifies the need to protect beneficial insects, paragraph 1.2 states: "Within the framework of integrated pest management, when carrying out chemical plant protection treatments, the following points should be considered: point 1. the selection of plant protection products in such a way as to minimise the negative impact of plant protection treatments on non-targeted organisms, in particular pollinating insects and natural enemies of harmful organisms."

VII.4. IMPACT OF AGROTECHNOLOGY ON BIODIVERSITY

Agrotechnology in winter oilseed rape cultivation has a great influence on beneficial organisms. When performed in compliance with good practices, it has first and foremost a beneficial effect on the crop. This keeps oilseed rape in good condition, so it is more competitive with weeds, and more resistant to the damaging effects of pests and pathogens. This way, the amount of plant protection products used can be significantly reduced.

PREVENTION

Maintaining the cleanliness of all cultivation tools, seed drill or combined harvester is an essential part of preventing diseases from spreading in and around the field. This way, it will be possible to reduce the amount of plant protection products, which will make the field and the surrounding areas friendly to beneficial entomofauna.

TILLAGE

An important element of tillage, which will have a beneficial effect on soil-beneficial organisms, is the abandonment of traditional tillage methods that involve a plough, in favour of other tools that deeply scarifies the soil without turning it over.

This will ensure that the soil environment is not disturbed. The ploughing system has the disadvantage of extracting the anaerobic microorganisms that live in the deeper soil layers to the surface. In contrast, aerobic microorganisms living on the soil surface are moved together with the soil to the bottom of the furrow, where anaerobic conditions prevail. This unfavourable situation has a negative impact on beneficial soil organisms. No-plough also has the benefit of increasing the number of earthworms in a field. For the protection of beneficial microorganisms as well as earthworms in oilseed rape cultivation, two tillage systems are very well suited, in which the plough is abandoned in favour of other agricultural tools. These are whole-crop tillage and strip-till technology. When protecting soil organisms, it is important to remember to till as much as it is necessary for the proper growth and development of oilseed rape, but as little as possible.

IMPROVEMENT OF SOIL FERTILITY AND BIOLOGICAL LIFE

Improving soil fertility has a beneficial effect on the biological life of the soil and, more specifically, its organisms. Improving soil fertility means introducing organic matter into the soil profile which, once mineralised, will have a beneficial effect on the crop and the beneficial organisms living in the soil. Organic matter can be introduced in the form of manure, compost or straw. When using straw, one must remember that it is a source of many nutrients, both macro- and microelements. The most important macronutrients are nitrogen, phosphorus, potassium, magnesium and calcium. Important micronutrients are boron, molybdenum, copper, zinc, and manganese. The component content in straw varies. It depends mainly on the species grown and the amount of nutrients taken up by the plant during growing season. With the straw harvested after the grain harvest, 15 to 45 kg N/ha, 30 to 62 kg K/ha and 6 to 12 kg P/ha are introduced into the soil. Straw and crop residues after rape provide more nutrients.

After mixing them with soil, 80 to 144 kg N/ha, 60 to 90 kg K_2O/ha and 6 to 12 kg P_2O_5/ha are introduced. The compounds in the straw are released by mineralization. The speed of this process depends on several factors. The most important of these are the amount and frequency of precipitation, as well as soil and air temperature. An equally important factor is that it is properly grinded. Straw is a valuable source of organic matter. The amount of organic matter introduced depends on the species grown, the variety and the technology used. On average, 3 to 5 t of crop residues per hectare should be introduced into the soil profile after the cereal harvest. After winter oilseed rape, the amount of straw and crop residues is much higher, ranging from 10 to 12 t. Their incorporation into the soil results in an increase in the humus content within. This is important because with more humus, the fertility of the soil increases significantly. When using straw to improve the fertility as well as the biological life of the soil, be sure to sow nitrogen in the form of mineral fertilizer on the scattered straw. A good solution is to use urea. The dose of nitrogen delivered in pure form per tonne of straw should amount to 6 to 10 kg. The applied fertilizer should be distributed evenly over the entire field. Giving up the use of nitrogen can have serious consequences, as the ratio of carbon to nitrogen will be disturbed, and this can be reflected in the quantity and quality of the yield obtained.

Another way to improve soil fertility and biological life is to apply manure. It is a very important organic fertilizer. It consists of bedding (usually straw), faeces and urine of the animals kept. The chemical composition and its value varies and depends on many factors. The most important of these are the species and age of the animals, their use and how they are fed. The type of straw used as bedding plays a very important role in the chemical composition of manure. No less important factor influencing the quality of manure is the way it is stored. Inadequate manure storage contributes to high losses of its components. When storing manure, make sure it is stacked evenly in compacted piles. Storing manure in this way will reduce desiccation, too much aeration and rapid fermentation. Consequently, nutrient losses, especially nitrogen, will be decreased. It is estimated that an average application of 30 t per ha introduces 750 kg of dry matter, 6000 kg of organic matter, 135 kg of nitrogen, 75 kg of phosphorus, 180 kg of potassium, 120 kg of lime, 45 kg of magnesium into the soil, 15 kg sulphur, 150 g boron, 900 g zinc, 12 g cobalt, 1.8 kg manganese, 120 g copper, 18 g molybdenum.

Using effective microorganisms is another way to restore soil properties, fertility, capability, and biological life. This way it will be regenerated, which will translate into the restoration of properties that determine the absorption of nutrients, both macro- and microelements.

Increasing the humus content and the impact on beneficial soil organisms is a long-term process, so works on it must be carried out continuously.

VIII RECOMMENDATIONS AND PROPOSALS FOR PROMOTING (AMONG PRODUCERS) THE USE OF BIOLOGICAL AGENTS AND ALTERNATIVE METHODS OF PROTECTION IN ORDER TO MAINTAIN AND POTENTIALLY INCREASE THE EFFECTIVENESS OF WINTER OILSEED RAPE CULTIVATION

VIII.1. OPPORTUNITIES GENERATED BY THE COMMON AGRICULTURAL POLICY

Oilseed rape is an agricultural plant heavily exposed to the negative impact of pests, therefore entirely ecological cultivation is practically impossible to implement without accepting losses in the amount and quality of seed yield, which may amount to more than 50% of the yield. In Poland, there is practically no large-scale cultivation of oilseed rape in the organic system. This is partly due to the fact that as a result of breeding work, modern oilseed rape varieties have been almost deprived of glucosinolates, which on the one hand limited the development of many diseases and pests, but on the other hand prevented feeding most animals with oilseed rape meal. Thanks to genetic advance, it has been possible to reduce the content of anti-nutritional compounds in this plant, at the expense of a decrease in the tolerance of varieties to certain diseases and pests. The presence of agrophages resulting from weather conditions (including climatic changes), the application of simplified agrotechnology as well as various legislative changes limiting the possibilities of comprehensive protection of this plant against pests also constitute major negative factors.

Currently, among all agricultural plants grown in Poland, oilseed rape (mainly winter oilseed rape), requires the most – just after potatoes and sugar beet – intensive chemical protection against agrophages. It is estimated that the average use of active substances deployed for the protection of this plant is 1.74 kg/ha. For this reason, further withdrawal of active substances that are used in plant protection products will become an increasing problem over time and can lead to seed yield losses of up to 20-50%, not to mention quality losses estimated at 10-30%. If the access to equally effective non-chemical methods is not provided, as the use of chemical methods of protection is reduced, oilseed rape becomes one of the most threatened crops in terms of profitability of production.

It is highly unlikely that oilseed rape will be grown in a fully organic way in Poland, however, it is possible and necessary to implement sustainable methods of its cultivation on an even larger scale than at present, on the basis of current principles of integrated pest management. The basic action that should be taken aiming at supporting oilseed rape producers in the era of changing strategies for agrophage control is education, supported by the results of scientific research. It is becoming necessary to raise awareness within the field of rational use of chemical plant protection products in order to prepare producers in advance for changes related to the further withdrawal of active substances. This can be done through intensive training, both theoretical and practical, including analysis of scientific experiments presenting specific solutions. An additional activity is the implementation of non-chemical solutions on an increasing scale, e.g. in the form of developing biological control methods based on microbial or macrophage-based biopreparations that are already present on the market. The first steps towards progress have already been taken: one of them is the introduction of biopreparations based on the fungus *Coniothyrium minitans* (Contans WG) for the purpose of limiting oilseed rape infestation by the organisms which cause white mold. Another solution to limit diseases is to implement biopreparations based on the fungus *Pythium oligandrum* (Polygreen Fungicide WP) to limit stem canker and white mold. *Bacillus amyloliquefaciens* strain MB1600 is is used for the purpose of protecting oilseed rape against stem canker. The use of biological control requires a broader knowledge of action mechanisms of such biopesticides, but also of the factors that affect their effectiveness, not to mention the correct application.

As far as biofungicides are concerned, it should be mentioned that the market offers various solutions against plant diseases, thus farmers are counting on biopreparations based on fungi from the *Trichoderma genus*, e.g. *Trichoderma asperellum*, which could also be implemented for oilseed rape protection against some pathogens. On the European, but also the domestic market there are various biopreparations based on different species of the fungus *Trichoderma*, therefore it is advisable to verify whether they will show proper efficiency in the field conditions, even if only through additional support of various types of biostimulants.

The latter may play an important role in reducing, for instance, plant responses to various biotic and abiotic stresses, although this theory should be verified by scientific units.

A possible solution to support oilseed rape growers in the fight against diseases of this plant would be to implement biopreparations based on the *Bacillus subtilis* bacterium, which exhibits fungicidal and fungistatic properties, e.g. in the case of noble rot or early blight. The fungi *Aureobasidium pullulans* and *Gliocladium catenulatum* also show similar properties against the cause of noble rot.

Depending on the type of cultivation, alternatives to chemical protection are also being explored; these include various extracts (e.g. garlic), concentrates (e.g. grapefruit), oils (e.g. tea tree) or algae extracts. Perhaps some of these solutions will prove useful in improving the health of oilseed rape plants.

For the time being, methods of pest control in oilseed rape crops are less likely to be applied, although certain biological control options would be applicable here as well.

Apart from the broadly understood increase of environmental resistance by supporting beneficial organisms naturally occurring in agrocenosis, by means of creating the so-called ecological sites, it is also quite necessary to change the general attitude so that plant protection is based on limiting the population rather than ruthless extermination of pests. To maintain satisfactory yields it is not necessary to completely destroy pests that were found on a given plantation; on the contrary, it is even inadvisable due to its trophic relationships with other organisms. As long as they are not invasive or quarantine pests, monitoring, damage threshold and other preventive measures should be used to limit their development, while chemical protection should be deployed only as a last resort.

Precise planning of treatments allows for more efficient and responsible use of chemical plant protection. For the time being there are no commonly used biopreparations limiting populations of oilseed rape pests. Appropriate scientific literature presents an opportunity in the use of insecticidal nematodes e.g. *Steinernema feltie, Steinernema carpocapsae* or *Heterorhabditis bacteriophora* to control larvae of soil-hiding pests, or the nematode *Phasmarhabditis hermaphrodita* to control naked snails. Following the example of other cultivatiohns, it would be possible to verify, for example, the usefulness of Bacillus thuringiensis as well as entomopathogenic fungi such as *Beauveria bassiana* or *Metarhizium anisopliae* for the purpose of limiting the population of particular species of insect pests.

Biological control is a difficult topic due to its cost-intensiveness and not-always-satisfactory effectiveness which is influenced by many factors, including those independent from the producer. Here it becomes necessary to develop systemic solutions which would encourage farmers to use means which are already available. It seems that a solution which would, in a way, encourage oilseed rape growers to use biological control would be the implementation of subsidies compensating for the higher cost of purchase of biopreparations, which would also compensate for the potential risk of plant protection failure. However, the solution would have to be a comprehensive one, which would also encourage the implementation of broadly defined preventive means.

Producers should already be getting used to future changes that will severely limit the range of chemical solutions they can use. Agrophage monitoring is crucial to predict whether or not chemical treatments against certain pests and diseases are needed in a given growing season. This is because each year the turn out of agrophages might differ. There are years when virtually no intensive plant protection is required for weevils or the common pollen beetle, and the same is true of fungal diseases, so an inflexible approach to plant protection that assumes the implementation of standardized treatments without conducting an analysis of the situation in a specific field should be replaced with even more precise monitoring than is currently deployed. The development of signalling systems seems to be one of the most important actions that can reduce the number of crop protection treatments performed, so that these treatments are performed as needed.

In addition to a thorough analysis of the sanitary condition of crops, even more use should be made of the achievements of breeders, who introduce to the market varieties with increased tolerance to certain harmful organisms, including those better adapted to changing climatic conditions. Oilseed rape growers already cultivate several clubroot resistant varieties, as well as varieties with increased tolerance, e.g. to stem canker, white mold and *Alternaria brassicae*. However, cultivation of such varieties must be conducted in a responsible manner, as without implementing additional protective measures, pathogens can quickly attack even a resistant or tolerant varieties.

There is no doubt about the fact that even cultivation of oilseed rape resistant varieties must be supported by the use of appropriate agrotechnological measures, the primary aim of which is to prevent the development of numerous agrophages on a plantation. Thus, it is be necessary to extend the range of mechanical weed control methods, use herbicides in a more responsible manner (e.g. through administration of reduced or divided doses, implementation of effective adjuvants, or by dense sowing that limits excessive weed infestation.

It is also essential to implement crop rotation, balanced fertilization, as well as other relevant measures that ensure the establishment of optimal conditions for the development of plants and directly and indirectly support their natural defence mechanisms.

To sum up, it should be emphasized that the limitation of the use of chemical plant protection products in oilseed rape crops in connection with the continuous withdrawal of subsequent active substances will enforce implementation of alternative solutions, which will allow for the use of those chemical preparations that can still be used, keeping in mind that they should be supplemented and, where possible, replaced with non-chemical solutions, including biopreparations. This cannot be effectively put into action without combining the knowledge resulting from scientific research with practice and subsequent implementation of these solutions on a larger scale. It is more than likely that actions aiming at increasing the level of knowledge through various trainings and conferences will prove useful in the process of adapting to changing conditions. Oilseed rape, just like corn, is an example of an agricultural crop where several biological solutions have already been deployed to reduce the use of chemical plant protection products, however, this is still a drop in the ocean.

For now, complete replacement of chemical protection with biopreparations is not quite possible. Still, encouraging farmers, for example by means of establishing a system of subsidies and reliefs to implement non-chemical methods on a larger scale, seems to be a very good solution. On the one hand it provide scope for the reduction of costs, which are noticeably higher when biological instead of chemical methods are used; on the other hand, these financial means might serve as a compensation for possible yield losses that may occur due to the fact that biological methods are usually more susceptible to weather conditions in comparison to chemical plant protection product (although it depends on the preparation used). Considering the diminishing possibilities of oilseed rape protection against agrophages, in the near future it will be absolutely necessary to extend the monitoring of agrophages in oilseed rape crops, so that it will be easier to predict the need for and appropriate timing of carrying out protective treatments, be they biological or chemical. Having the knowledge with regard to what is already available on the domestic market in terms of possibilities of replacing certain chemical solutions, it seems that for the time being the best solution is the so-called sustainable agriculture, in which biological and chemical plant protection products are deployed simultaneously. Nevertheless, in the future the latter method, to an even greater extent than now, must be based on precise monitoring and careful selection of chemical preparations acting against the real threat posed by a given agrophage in a given growing season.

As part of the European *Green Deal*, the European Commission on May 20, 2020 adopted two Strategies: „*Farm to Fork*" and the "*Biodiversity Strategy*". These strategies specify that the use of plant protection products should be reduced by 50% within ten years, while fertilisation will be reduced by 20%. Currently, the EU is developing secondary legislation that precisely defines the requirements for individual agricultural and horticultural producers.

Restrictions on the use of plant protection products within individual states will be entered into the upcoming EU regulations. It goes without saying that countries which for many years have been using the largest amounts of chemical plant protection products should implement the most severe restrictions. A perfect example are the Netherlands, where as much as 10 kg/ha of active substances is used on average in plant protection products. Currently in Poland an average of only 2.5 kg/ha of active substances is used – that is 4 times less than in the Netherlands. If we consider the EU as a whole, the average use of active substances is 3.5 kg/ha, which means that Poland should reasonably increase the amount of chemical plant protection used by 1 kg/ha.

The average use of plant protection products in Poland and in the whole EU is calculated as the amount of kg/ha of active substances of plant protection products; therefore, the amounts used in particular countries can be compared. In Poland such final calculations are performed by the Institute of Plant Protection – National Research Institute. This information is provided by GUS and Eurostat.

In the EU 3.5 kg/ha of active substances is used on average; in Poland it is only 2.5 kg/ha. The highest amount of active substances is used in the Netherlands – 8, in Italy – 6.5, in Germany – 4.5 and in France and Spain – 4 kg/ha each. Only a few countries use smaller amounts of active substances than Poland: Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Lithuania, Latvia and Slovakia. In Poland the least amount of plant protection products is used in the production of agricultural crops (approximately 0.5 kg/ha in the cultivation of oats, spring barley, spring wheat and cereal mixtures. More than 1.3 kg/ha is used to protect winter wheat, which is used i.a. for flour production. In Poland, 1.74 kg/h of active substances is used in protection of winter oilseed rape. Larger amounts of active substances are used to protect potatoes – 3.5 kg/ha and sugar beet – 2.6 kg/ha. Horticultural crops, apple orchards in particular, require the use of approximately 10 kg/ha of active substances, however, in other countries leading in the production of apples (e.g. USA), these amounts exceed even 13 kg/ha. The EC *Farm to Fork* Strategy aims to reduce the use of plant protection products in EU by 50%. According to the data collected by Eurostat, 4 countries: France, Spain, Germany and Italy together use as much as 65% of all plant protection product used in the EU, while using only 45% of arable land. These countries should strive to enforce the most significant reduction in the use of chemicals in plant protection.

By implementing the EC Strategy, Poland may even reasonably increase the use of plant protection products in agricultural crops, while in some horticultural crops there should be a reduction in chemicalisation.

In the last two years, the EU has withdrawn approval for 20 active substances used in plant protection products, while only 3 new substances have been introduced. This situation raises the cost of crop protection, which in the near future will exceed the cost of crop fertilization. New active substances are subject to a 15-year patent-pending period and the cost of innovation is borne entirely by the farmer and gardener; as a consequence, the consumers are affected. In view of the increasing toxicological and environmental requirements, phytopharmaceutical companies do not plan to introduce new active substances, as the costs of innovation counted from the moment when an idea is conceived to the start of production amount to PLN 1 billion for a single plant protection product.

Reducing the chemicalization of plant protection will reduce the yield of plants by 16-50% and will impair the quality of plant raw materials by 12-50%. Such data was presented in an expert report drawn up by Kleffmann in 2016. The reduction of plant protection will reduce mostly the yield of sugar beet and potato, as the maximum decrease in production can reach up to 70%. Winter oilseed rape yields may be reduced by a minimum of 20% and by a maximum of 50%, while wheat and corn yields will be reduced by 30%. The quality of the yield will also deteriorate, as the lack of proper plant protection will increase the risks caused by mycotoxins, which are mostly carcinogenic substances. Limited plant protection will reduce the quality of wheat grain in particular (up to 70%), which might prove very dangerous for consumers.

The yield quality of winter oilseed rape can be reduced by 10 to 30%.

According to the expert opinion issued by Kleffmann, the costs of protection and production will also increase by 26 to 29%, mainly as a result of an extensive withdrawal of active substances and production of new preparations. Due to the fact that new preparations are subject to patent protection, they are more expensive; thus, a shortage of generics is predicted.

In November 2020, the U.S. Department of Agriculture (USDA) published Report 30, which states what impact the EC *Farm to Fork* Strategy might exert on EU agriculture. According to the report, EU oilseed rape production will be cut by 37.8%, while vegetable oil production will decline by 14.8%. At the same time, the use of plant protection products in the EU will decrease by 27.5%, while the level of fertilisation will be lower by 10.2%.

Unfortunately, production costs will increase – according to Kleffmann's expert report, the average financial commitments will be between 13 and 25% for agricultural crops. The maximum increase in protection costs will apply to cultivations of winter oilseed rape (39%) and wheat (31%), while in the case of corn an increase of ¼ is expected. The biggest contributor to increased plant protection costs will be climate change, resulting in an increased threat from agrophages. In addition, new plant protection products are becoming more and more expensive as launching innovations is an expensive venture, i.a. due to the patenting procedures. Moreover, in such situations we can often observe lack of generic preparations, which are several times cheaper. New plant protection products also have a very short lifespan, enforcing the users to carry out repeated treatments, which generate high costs.

At present, all new plant protection products have to meet very strict environmental and toxicological requirements. It is necessary to use short-acting active substances as long-acting preparations no longer can be used. This situation means that the grower has to repeat protective treatments very often, which in turn generates high production costs. A large limitation in the number of active substances and various types of chemical plant protection products leads to agrophages developing a resistance to preparations, which is still one of the major concerns for growers as the production costs rise dramatically.

Implementation of EC strategies increases the risk of pest resistance to plant protection products. It is best to alternate between different groups of chemical plant protection products that affect agrophages in distinct ways. The correct and precise use of plant protection products is also a very important prerequisite for preventing the development of resistance. It consists mainly in observing climatic conditions during protective treatment, as in optimal conditions preparations are the most effective, which makes it impossible for pests to develop resistance.

The problem of so-called off-label use across the whole EU is a significant issue, as farmers and gardeners, due to lack of specific recommendations for a given pest, unfortunately use other plant protection products that are currently available. They break the law that stipulates that pests must be treated according to the product label. In Poland, it is prohibited to use unregistered preparations and is subject to withdrawal of direct payments and liquidation of plantations at the expense of the user of illegal means.

The best approach is to apply integrated pest management, i.e. use modern non-chemical methods, the available agrotechnology, sow varieties resistant and tolerant to agrophages and use biological preparations which will only become more and more important in the future.

Biological agents are 2 to 5 times more expensive in comparison to chemical preparations. In Europe, 20 years ago Switzerland was the first country to introduce a financial subsidy of up to 50% for the use of biological agents. Several years ago a similar solution has been introduced in Austria, Belgium, Czech Republic, France, Slovakia; in Germany EUR 75 is paid per 1 biologically protected ha. The EU, planning to halve the use of chemicals and increase the share of organic crops to 25%, should introduce targeted payments that already have been established in some of the countries. Lack of subsidies inhibits any significant reduction of chemicalisation. A similar situation applies to the use of varieties tolerant or resistant to agrophages, especially pathogens. Unfortunately such varieties are 2 to 3 times more expensive in comparison to conventional varieties. The distribution of resistant varieties will allow for the reduction of chemicalisation, but it also requires the introduction of targeted subsidies. Chemicalisation can also be reduced by increasing the number of agrotechnological treatments carried out, which have been marginalised for many year in favour of simplified agrotechnology. Unfortunately, crop monoculture and simplified agrotechnology result in the need for increased use of chemical plant protection products, which is not in line with the integrated pest management and EC Strategies. The reduction in and limitation of herbicide use has enforced a return to the use of various weeders that effectively get rid of unnecessary plants. Modern weeders are controlled by image sensors to maximize the width of the row of crop growth that is simultaneously sprayed with herbicide. This modern technology reduces the amount of chemicals used by up to 90%. A similar system is mounted on sprayers, allowing chemicals to be applied only where agrophages are present.

Modern sprayers with image readers make it possible to reduce chemicalisation by up to 50%, which is consistent with EC Strategies. Modern sprayers and weeders are unfortunately very expensive and targeted subsidies should therefore be introduced. Without such action, there can be no innovation to reduce chemicalisation.

In winter oilseed rape production biological agents are currently are almost never used, despite the fact that 6 preparations have already been registered. The main reason for the rare usage of biological methods in the field cultivation of agricultural and horticultural crops is the unsatisfactory effectiveness against agrophages and dependence on agroclimatic conditions.

Currently in Poland a total of over 2500 plant protection products are registered, of which only approximately 50 are biological preparations. A similar situation occurred a few years ago in other EU countries, but the introduction of targeted subsidies for the purchase of biological products; as a result, the proportion of biological preparations already exceeds 10% and the percentage is still rising. In Poland, in addition to subsidies for the purchase of biological preparations, large financial resources from the CAP 2021-2027 budget should be used to train advisors and producers of agricultural and horticultural plants. The use of biological methods requires improved precision and knowledge due to the optimal conditions of action on pests.

Precise application of plant protection products makes it possible to reduce chemical use by up to 50%, which is in line with EC Strategies and the integrated pest management.

On plantations, agrophages are always unevenly distributed and therefore there is often no need to carry out treatments on the entire plantation area. By using image readers which are mounted in front of the sprayer, it is possible to identify if an infestation is present in a particular area of the plantation. Currently such systems are rather expensive, but in a few years they will be much more common, just like facial image analysis is already widely used in smartphones.

VIII.2. EXAMPLES OF SOLUTIONS IMPLEMENTED IN OTHER EU COUNTRIES

It is extremely important to educate farmers within the field of using biological agents. Training should ensure that they have a broad knowledge of their mechanisms of action, effectiveness, the influence of biotic and abiotic conditions on their effectiveness, and much more. It should also take into account issues connected with improving the spatial structure of a farm to increase the level of biodiversity, efficient forecasting and signalling the appearance of agrophages.

Most of the available biological agents do not guarantee improved efficiency when compared to chemical agents. It depends on numerous factors, both biotic and abiotic. Agricultural producers need to be properly trained to understand how biological agents work, how to use them and what are the advantages and disadvantages of their deployment. The use of these agents requires a lot of knowledge, since in many cases incorrect application proves ineffective. A major advantage of biological agents is the fact that they are safe for the environment. They have a positive impact on the biodiversity of the agricultural landscape, are safe for the consumer and beneficial organisms, do not require a withdrawal period and, once introduced into the environment, remain effective for a long time; under natural and optimal conditions for their development, can reduce pest populations without the need to repeat the treatment. Other positive features of biological agents include: they do not leave any residues, are not toxic to entomophages, are often targeted at specific groups of organisms (e.g. affect only aphids), reduce the use of chemical plant protection products and protect environmental biodiversity. They also have disadvantages, such as sensitivity to environmental conditions (temperature, humidity), expensive production and application, short lifespan in a preparation, require precise performance of treatment and have a slow mode of action. This may discourage producers from using them, therefore it is important to introduce subsidies for the use of biological agents. In Europe, 20 years ago Switzerland was the first country to introduce a financial subsidy of up to 50% for the use of biological agents. Several years ago a similar solution has been introduced in Austria, Belgium, Czech Republic, France, Slovakia; in Germany EUR 75 is paid per 1 protected ha. In other countries the use of biological methods of plant protection accounts for 50%-60% of incurred costs documented by an invoice issued to the beneficiary. The Common Agricultural Policy 2021-2027 assumes that eco-schemes should allow for subsidies for the use of biological methods.

The Common Agricultural Policy 2021–2027 also aims at supporting the development of certified Integrated Plant Production, including of winter oilseed rape. In Italy, subsidies for 1 ha of certified agricultural crops were introduced in 1995. They amount to EUR 150 per hectare, while for horticultural crops they are three times higher.

Subsidies for biological plant protection should be independent of the certification of production systems. Preparations based on macro-organisms (parasitic and predatory insects, insecticidal nematodes) should also be co-financed.

In Poland they are not subject to registration, so they should be recorded and correspond to the list of organisms recommended by the European and Mediterranean Plant Protection Organization (EPPO).

VIII.3. SUPPORT UNDER NATIONAL FORMAL AND LEGAL SERVICES

From 2022, the Ministry of Agriculture and Rural Development plans to introduce higher subsidies for voluntary (but certified) Integrated Plant Production, including of winter oilseed rape. The payments will apply to each certified hectare, and not, as it is now, to the whole farm (which amounts to PLN 2850 in the period of one year).

The Ministry of Agriculture and Rural Development, along with the Institute of Plant Protection – National Research Institute has drawn up a list of obligatory operations and treatments in the integrated production system for winter oilseed rape (Table 31). Fulfillment of all the conditions in the list will serve as a basis for being recognised as eligible for subsiding Integrated Plant Production, including of winter oilseed rape. The most important requirements as indicated in the Integrated Production checklist are: A 4-year break in winter oilseed rape cultivation, the use of certified and treated seed, completing at least one treatment with the use of biological plant protection products and introducing a ban on desiccation of winter oilseed rape before cereals (Table 31).

According to the data gathered by the Main Inspectorate of Plant Health and Seed Inspection, in 2019, certificates of Integrated Production of winter oilseed rape were granted to only 28 plantations covering an area of 250 ha, which is merely a margin of the entire winter oilseed rape production in Poland.

TABLE 31. List of obligatory operations and treatments of the integrated production system for winter oilseed rape

Mandatory requirements (100% compliance, i.e. 21 points)			
No.	**Control points**	**YES/NO**	**Notes**
1.	Maintaining at least a 4-year break between subsequent cultivations of oilseed rape in the crop rotation.	☐/☐	
2.	Deploying appropriate crop rotation – planting preceding crops as indicated in the methodology and avoiding plants from mustards family as the main crop and the catch crop.	☐/☐	
3.	Maintaining at least 50 m of spatial separation from other mustards crops.	☐/☐	
4.	Implementing agricultural practices on stubble field before sowing without applying pre-emergence and soil-applied herbicides.	☐/☐	
5.	Using certified and treated seed according to the ESTA standard.	☐/☐	
6.	Selection of varieties with increased resistance/tolerance to causes of disease e.g. stem canker, turnip yellow virus.	☐/☐	
7.	Testing soil pH and the content of the main nutrients (NPK, S) in soil, in accordance with the cycles indicated in the methodology, confirmed in the relevant documents.	☐/☐	
8.	Applying in appropriate periods and in suitable doses of fertilization rich in macro and microelements, depending on the type and pH of soil, after prior conducting a nutrient balance assessment, confirmed in the relevant documents.	☐/☐	
9.	Sowing only in periods appropriate for a given area, according to the relevant standard and while maintaining appropriate sowing parameters.	☐/☐	
10.	Using agricultural practices as the first step in weed control, and in the case of chemical plant protection products – using a suitable post-emergence herbicide in the autumn at the proper dose, taking into account the level of weed susceptibility and harmfulness thresholds.	☐/☐	

TABLE 31. List of obligatory operations and treatments of the integrated production system for winter oilseed rape; cont.

Mandatory requirements (100% compliance, i.e. 21 points)			
No.	**Control points**	**YES/NO**	**Notes**
11.	Systematic monitoring (at least once a week) from the moment of emergence to the beginning of ripening of whether or not diseases occur (stem canker, *Alternaria brassicae*, clubroot, noble rot, white mold, turnip yellow virus and others).	☐/☐	
12.	Systematic monitoring (at least once a week) from the moment of emergence to the beginning of ripening of whether or not pests occur (cabbage fly, aphids, flea beetles, weevils, common pollen beetle, brassica pod midge and others) using appropriate methods (direct observation of plants, yellow bowls, etc.)	☐/☐	
13.	Using plant protection products after exceeding the value of damage threshold for diseases and pests by deploying the disease prediction system (SPEC) and (or) Signalling of Agrophages Platform.	☐/☐	
14.	Completing at least one treatment with the use of biological plant protection products.	☐/☐	
15.	Using only plant protection products from the list of products authorised for use in integrated production of oilseed rape.	☐/☐	
16.	Rotational application of active substances of plant protection products from different chemical groups in order to prevent agrophages (weeds, pests and pathogens) from developing resistance, taking into account the scope of protection established in previous seasons.	☐/☐	
17.	Using products in a manner that is safe for the honeybee and other pollinators and beneficial organisms.	☐/☐	
18.	Managing the cultivation in a manner allowing for minimising the need for weed control without the need to carry out a desiccation treatment before harvest.	☐/☐	
19.	Cleaning of machinery and equipment used in crop cultivation.	☐/☐	
20.	Creating appropriate conditions for the presence of birds of prey, i.e. setting up perches (at least 1 perch per 5 ha), and in the case of larger plantations – several perches.	☐/☐	
21.	Placing “houses” for red mason bees or mounds for bumblebee nests (at least 1 perch per 5 ha) – and in the case of larger plantations – several houses or mounds.	☐/☐	

Note: The implementation of all requirements from the list of obligatory operations and treatments in the integrated production system for winter oilseed rapes should be documented in the notebook of integrated plant production.

IX SUMMARY AND CONCLUSIONS

IX.I. SUMMARY

In Poland, winter oilseed rape is one of the most important oilseed crop, and currently its sown area is constantly increasing and amounts to almost 1 million ha. In agroclimatic conditions of Poland there are almost 100 agrophages, of which 15 pests, 8 pathogens and 10 weeds are the most important for economic reasons.

The introduction of the obligation to use integrated pest management as of January 1, 2014, contributed to the reduction in the use of plant protection products in winter oilseed rape from 1.97 kg/ha of active substances to only 1.74 kg/ha. Currently, herbicides are mostly used (0.92 kg/ha); they are followed by fungicides – 0.45 kg/ha and insecticides – only 0.28 kg/ha of active substances. In Poland, 2.5 kg/ha of active substances is used on average, while in the entire EU it is 3.5 kg/ha.

The EC Strategies "*Farm to Fork*" and "*Biodiversity Strategy*" recommend a 50% reduction in the use of plant protection products within 10 years, which should be applicable only to the 10 EU countries using plant protection products in the amount exceeding the average; the countries using fewer preparations should rationally increase the chemicalization of production, including through the use of non-chemical methods, mainly biological agents.

Currently, 539 pesticides for controlling the population of agrophages (i.e. diseases, weeds and pests) of winter oilseed rape have been registered in Poland, including: 230 herbicides, 233 fungicides, 118 insecticides, 24 molluscicides, 17 plant growth regulators, and 4 seed treatments. After possible withdrawals of subsequent active substances, these numbers will decrease to approximately 150 herbicides, only 50 fungicides and almost 60 insecticides.

Integrated protection of oilseed rape favours the use of seed treatments that contain pesticides and pathogens. Seed treatment of certified seed should only be carried out by professional companies that hold European Seed Treatment Assurance certificate; in Poland its issuance is supervised by the Polish National Seed Chamber and the Polish Centre for Accreditation. There are currently 13 companies certified by ESTA to treat oilseed rape. They are located in various regions of oilseed rape cultivation.

The newly introduced cultivation of resistant and tolerant varieties to pathogens and pests will allow to limit the negative impact of the withdrawal of active substances used in oilseed rape. According to the Polish National List of Agricultural Plant Varieties, currently in Poland there are only 13 resistant varieties and tolerant to clubroot, which is not enough to solve the problem arising from the withdrawal of thiophanate methyl found in the four fungicides used to control this – very damaging from the economic point of view – pathogen.

In addition, the Polish National List of Agricultural Plant Varieties names 38 winter oilseed rape varieties that are resistant and tolerant to turnip yellow virus (TuYV). This virus is mainly caused by the green peach aphid. The List also features 45 varieties with genes such as Rlm7 and Apr 37, which are responsible for oilseed rape resistance against stem canker. Cultivation of varieties that are tolerant and resistant to pathogens and pests allows for reducing production chemicalisation, which is in line with the integrated protection of oilseed rape crop and meets the objectives of the EC Strategy.

Limiting the use of pesticides enforces introduction of biological methods, an example of which are nonpathogenic beneficial fungi – *Pythium oligandrum*, which reduce e.g. white mold in oilseed rape. In the near future, the number of various modern biological agents will increase rapidly, which will make it possible to at least partially limit the negative impact of active substances used in chemical plant protection products withdrawal on winter oilseed rape production.

Oilseed rape cannot be cultivated in the organic system, without using plant protection products. It can be cultivated in the so-called pro-ecological system through precision sowing and mechanical weeding of inter-rows. The threat of diseases is reduced thanks to lower density of the crops on the field. In addition, it is advisable to sow varieties resistant to diseases such as the aforementioned yellow turnip virus, and in regions exposed to clubroot – resistant varieties with the Rlm 7 gene, i.e. tolerant to *Phoma*. The future lies precisely in plant breeding and varieties that have several genes which render them resistant to various diseases. Unfortunately, this is not applicable to pests. The European Union, in accordance with the assumptions of the European Green Deal for 2030, intends to withdraw from the market as much as half of the currently used plant protection products. More and more limitations are introduced regularly. Subsequent active substances, acting on pests, diseases and weeds are continuously disappearing from the market. The amount of available active substances is constantly decreasing, hindering the implementation of integrated pest management. Treatments should be effective up to the development stage of the eighth leaf of oilseed rape. In the last century, growers used organophosphate and carbamate-based treatments that did not need to be repeated for a period of several weeks. Now treatments must be repeated every three weeks – in fact, in most cases it should be done even more frequently. As a result, farmers have to carry out two or – when the population of pests is high and the growth period long (which is the case particularly in western and southern Poland) – even three or four pest control treatments. At the time when the use of neonicotinoid seed treatments was prohibited, even 5-6 treatments were performed in autumn. The number of treatments depends on the pest pressure; warm weather only increases it (as insects love warmth), therefore their population is increasing every year. In the near future, precision sowing of oilseed rape will probably become the norm, similarly to sowing beet in wide rows. In addition, oilseed rape should be grown in fields that cover at least 10 hectares, as pests tend to appear in the border areas. When a field covers only 1 ha, then the pressure of agrophages is much higher because the whole field is rapidly infested; economic losses quickly follow. At present, in Poland oilseed rape is grown by 92,000 growers; precision sowing will make it necessary to take care of "every plant" in the field. Above all, hybrid varieties that are characterised by a fast initial growth and cover the inter-rows in a short period of time will be sown. Plant breeding is directed towards changing the crop habit of winter oilseed rape, which results in enhanced competition with weeds. In Germany, only 5% of oilseed rape crops are open-pollinated varieties, the vast majority of which are hybrids; soon this will also be the case in Poland. In breeding, attention is being paid to improving the root system of winter oilseed rape so that the plants further develop the taproot system. This will increase the resistance of varieties to drought or long-term water shortages. In the future, breeding should also create varieties that will regenerate quickly after damage, e.g. caused by pests. The diameter of the root collar of the future oilseed rape will be 2 cm rather than the current 8 mm. Such a plant will have an even higher yield potential, as well as a greater ability to regenerate after the winter. Spray treatments against weeds will be carried out only locally – close to the plant, and in the inter-row strip of land weeders with image recognition system will be used. Thus, herbicide treatments will not be applied to the entire field.

For several years breeding has succeeded in effectively reducing the susceptibility of winter oilseed rape varieties to pod cracking, especially through the use of radish genes, conditioning resistance to cracking. This minimizes yield losses due to adverse weather events such as heavy rainfall, storms, etc., which occur more and more frequently during the ripening period of oilseed rape. In many new varieties entered in the Polish National List of Agricultural Plant Varieties this feature is clearly improved. There are already more than 30 such varieties and it is expected that more will appear soon. Cracked pods not only reduce seed yield, but also increase the risk of oilseed rape self-seeding for the successive cropping, mainly wheat. New generations of pests multiply on oilseed rape self-seeding, which results in the development of diseases such as the stem canker.

Winter oilseed rape has been the subject of intensive breeding work for many years. Numerous new varieties appeared as a consequence. After an appropriate period of conducting research and registration, they are put into production. The annual varieties research conducted within the framework of the Post-Registration Variety Testing System (PDO) allows us to state that new varieties of winter oilseed rape bring breeding progress, which is expressed, among others, by:

- increase in fertility,
- increasing the fat content of the seeds,
- reduction and stabilisation of the glucosinolate content in most varieties,
- the possibility of growing some varieties effectively on medium soils,
- change in plant habit, which also reduces crop lodging,
- reducing the amount of seed sown and the planting density of the crop area,
- increased resistance to infection caused by major pathogens, in particular stem canker (*Phoma*), white mold (*Sclerotinia sclerotiorum*) and *Alternaria brassicae*, as well as the development of new varieties with increased resistance to clubroot and varieties resistant to turnip yellow virus (TuYV),
- increased resistance to pod cracking and seed shedding.

Currently, the main source of breeding progress in oilseed rape cultivation are hybrid varieties.

The requirements concerning the necessity of implementing integrated oilseed rape protection, applicable as of 2014, result in the need to breed, and then test

and implement cultivation of varieties tolerant and resistant to harmful organisms. The healthiness of oilseed rape varieties is an important criterion for assessing their economic value in the process of registration, and then recommending varieties for wide cultivation.

Genetic resistance of varieties to diseases is – and will continue to be in the future – an environmentally safe way to maintain the health of field crops of oilseed rape. The widespread use of varieties resistant or tolerant to various adverse factors will bring both economic and environmental benefits. The traits that determine better productivity under plant stress conditions are also an important element in selecting a variety for cultivation.

Oilseed rape growers will more and more frequently for cultivation select varieties which are tolerant to low temperatures, drought and other abiotic stresses, especially in the context of pending climate changes. Also, the quality of the seed yield will always be very important, especially in the case of seeds used in the food industry.

Future directions in winter oilseed rape breeding

- resistance to pathogenic organisms causing diseases, i.e. white mold, verticillium wilt of oilseed rape, cylindrosporiosis and other diseases,
- resistance to pests: aphids, cabbage fly, flea beetles,
- regeneration of roots damaged by pests, pathogens and low temperatures,
- regeneration of aboveground parts which are damaged by game, birds,
- return to the typical taproot (improved use of water and fertilizer),
- varieties useful for spot sowing in wide rows,
- varieties characterised by an equally long ripening process and non-cracking pods (a response to the withdrawal of desiccants),
- varieties suitable for low-volume technologies.

Negative effects of withdrawal of active substances used in plant protection products from winter oilseed rape production technology:

- problems with controlling many agrophages and ensuring proper protection for oilseed rape,
- increase in agrophage resistance resulting from a lower rotation of chemical groups and active substances,
- increased use of plant protection products, as the more recent preparations have a very short lifespan,
- a reduction in the size and quality of the seed yield obtained,
- increased production costs, as biological agents are much more expensive,
- lower farm incomes, as new preparations require a higher number of treatments to be carried out and patents on active substances increase costs,
- an increase in the risk of using plant protection products in contravention of the law, i.e. the label,
- an increase in the risks associated with illegal imports of plant protection products.

IX. 2. CONCLUSIONS AND RECOMMENDATIONS

FARM TO FORK STRATEGY

1. The EC *Farm to Fork* Strategy recommends a 50% reduction in the use of plant protection products within 10 years. This provision is applicable only to the 10 EU countries using plant protection products in the amount exceeding the average; the countries using fewer preparations should rationally increase the chemicalisation of production, including through the use of non-chemical methods, mainly biological agents.
2. The EU enforces the withdrawal of numerous active substances of plant protection products, however, it does not suggest any new solutions, which is a problem for winter oilseed rape growers. Efforts should be made to ensure that new substitutes for the chemicals that the EU is phasing out are launched on the market, allowing for the implementation of integrated pest management.
3. A 50% reduction in the use of chemical plant protection products under the CAP 2021-2027 will require the provision of financial support to winter oilseed rape growers, targeted at:
   - purchase and use of biological preparations,
   - purchase of certified seed of varieties tolerant or resistant to agrophages,
   - increasing the requirements for integrated plant production,
   - improving the knowledge of advisers and farmers.
4. Without budgetary support under the CAP 2021-2027, it will be impossible to implement the EC *Farm to Fork* Strategy, which may become merely another utopia of the European Union, also within the scope of integrated protection and production of winter oilseed rape.
5. Implementation of the EC *Farm to Fork* Strategy without financial support will make the EU dependent on food imports, including of oilseed rape, which cannot guarantee the security of individual countries.
6. The EC *Farm to Fork* Strategy will increase the cost of winter oilseed rape production, which, in the absence of additional funding from the EU budget, will affect food prices.
7. According to current knowledge, chemical plant protection products used in winter oilseed rape production can be replaced by biological preparations only

to a small extent; these preparations should be obligatorily registered under a simplified procedure.

8. The use of bioregulators, biostimulants and adjuvants in winter oilseed rape cultivation should be extended through introducing a simplified registration procedure. As a result, the level of chemicalisation of winter oilseed rape protection will be reduced.
9. There is an urgent need to increase the number of agrophage-resistant and agrophage-tolerant oilseed rape varieties in the Polish National List of Agricultural Plant Varieties.
10. The EC *Farm to Fork* Strategy, which recommends reducing the level of chemicalisation of certified Integrated Plant Production, including winter oilseed rape, will be unfit for implementation without the provision of financial support under the CAP 2021-2027

THE BIODIVERSITY STRATEGY

1. The Biodiversity Strategy pertains to organic farming, which by 2030 should constitute at least 25% of agricultural land in EU countries.
2. In Poland winter oilseed rape is infested, damaged and devoured by approximately 100 species of agrophages, which makes it impossible to cultivate and protect it by means of deploying the organic system, however, actions should be taken in order to establish the pro-ecological system of oilseed rape.
3. Initiatives aiming at diversification of the landscape should be promoted through the preservation or creation of such elements as: ponds, baulks and farmland woodlots, which provide habitats, place for development, shelter and food for many animal species. The use of biological methods against agrophages includes using a conservation method to modify the agricultural landscape by humans to create suitable conditions for the development of beneficial organisms in the environment.

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Publication was funded by Oilseed Promotion Fund