MAIN INSPECTORATE OF PLANT HEALTH AND SEED INSPECTION

DRAFT

Methodology for the integrated production of white, brown and black mustard

(*Sinapis alba*, *Brassica juncea*, *Brassica nigra*)

Approved

pursuant to Article 57(2)(2) of the Plant Protection Products Act of 8 March 2013 (consolidated text: Journal of Laws [Dziennik Ustaw] 2024, item 630)

by

the Main Inspector of Plant Health and Seed Inspection

INTEGROWANA PRODUKCJA
URZĘDOWO KONTROLOWANA

Approved by

~~*/signed electronically/*~~

Warsaw, March 2025

PLANT PROTECTION INSTITUTE — STATE RESEARCH INSTITUTE
ul. Władysława Węgorka 20, 60-318 Poznań

Methodology developed as part of task 1.5.

‘Development of Integrated Plant Production Methodologies’

financed by the Ministry of Agriculture and Rural Development

2025

PLANT PROTECTION INSTITUTE — STATE RESEARCH INSTITUTE
ul. Władysława Węgorka 20, 60-318 Poznań
email: upowszechnianie@iorpib.poznan.pl, www.ior.poznan.pl

Collective paper edited by:
Dr Ewa Jajor, Dr Przemysław Strażyński and Prof. Marek Mrówczyński

Authors:
Dr Ewa Jajor[1]
Dr Przemysław Strażyński[1]
Dr Marek Wójtowicz[2]
Prof. Marek Korbas[1]
Prof. Marek Mrówczyński[1]
Prof. Danuta Sosnowska[1]
Prof. Jacek Przybył[3]
Dr Przemysław Kardasz[1]
Dr Joanna Horoszkiewicz[1]
Dr Jakub Danielewicz[1]
Jacek Broniarz[4]
Dr Joanna Zamojska[1]
Dr Monika Jaskulska[1]
Dr Roman Kierzek[1], Professor at the Institute of Plant Protection — State Research Institute
Dr Kinga Matysiak[1], Professor at the Institute of Plant Protection — State Research Institute
Dr Grzegorz Gorzała[5]
Marcin Bombrys[1]

[1] Institute of Plant Protection — State Research Institute, Poznań
[2]Plant Breeding and Acclimatisation Institute — State Research Institute, Poznań Branch
[3]Poznań University of Life Sciences
[4]Central Research Centre for Cultivar Testing, Słupia Wielka
[5]Main Inspectorate of Plant Health and Seed Protection, Warsaw

1. PREFACE

Integrated plant production (IP) is a management system that takes into account the use of technology and biological progress in a sustainable manner in the cultivation, protection and fertilisation of plants while ensuring the safety of the natural environment. The essence of integrated plant production is therefore obtaining crops satisfactory for both producers and consumers, in a way that does not interfere with the protection of the environment and human health. Its strategy is more complex than that of production using conventional methods. As much as possible, natural biological mechanisms supported by the rational use of plant protection products are used under the integrated plant production scheme. In modern agricultural production technology, the use of fertilisers and plant protection products is necessary and extremely beneficial, but at times it may also threaten the environment. In integrated plant production, however, special attention is paid to the reduction of the role of chemical plant protection products used to limit pests to a level that does not threaten crops, fertilisers and other resources needed for plant growth and development to create an environmentally safe system while ensuring high-quality crops free from residues of substances known to be harmful (heavy metals, nitrates, plant protection products).

2. LEGAL REGULATIONS APPLICABLE TO INTEGRATED PRODUCTION (IP) AND RULES FOR ITS CERTIFICATION

2.1. Integrated pest management as the basis for integrated production (IP)

Integrated plant protection consists of protecting crops against harmful organisms, using all available methods, in particular non-chemical methods, in a way that minimises risks to human, animal and environmental health.

Integrated protection consolidates and systematises practical knowledge about organisms harmful to plants (especially about their biology and harmfulness) in order to determine optimal deadlines for taking action to control these organisms while taking into account naturally occurring beneficial organisms, i.e. predators and parasites of organisms harmful to plants. It also reduces the use of chemical plant protection products to a necessary minimum, thus reducing environmental pressure and protecting the biodiversity of the agricultural environment.

Professional users who use plant protection products are obliged to take into account the requirements of integrated plant protection set out in the Regulation of the Minister for Agriculture and Rural Development of 18 April 2013 on requirements for integrated plant protection (Journal of Laws [Dziennik Ustaw] 2013, item 505). According to the aforementioned Regulation, an agricultural producer should use all available measures and methods of protection against pests before applying chemical plant protection with a view to reducing the use of pesticides. The provisions of this Regulation put a strong emphasis on, inter alia, the use of crop rotation, suitable varieties, compliance with optimal deadlines, the use of appropriate agrotechnology, fertilisation, and prevention of the spread of harmful

organisms. One of the requirements is also to protect beneficial organisms and create favourable conditions for their occurrence, in particular pollinators and natural enemies of harmful organisms. The use of chemical plant protection should be preceded by monitoring activities and supported by appropriate scientific instruments and counselling.

Under the current law, only plant protection products authorised for marketing and use on the basis of authorisations (or parallel trade permits) issued by the Minister for Agriculture and Rural Development may be used for chemical protection of plants.

The list of plant protection products authorised in Poland is published in the register of plant protection products. Information about the scope of pesticide use for particular crops is placed on the product's label. The Ministry of Agriculture and Rural Development provides a register and labels at: https://www.gov.pl/web/rolnictwo/ochrona-roslin.

Information on plant protection products authorised for integrated production is published in the Online Pest Warning System at: https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.

It is the responsibility of each user to read and follow the label before the application of a plant protection product.

In accordance with the Regulation of the Minister for Agriculture and Rural Development of 31 March 2014 on conditions of use of plant protection products (Journal of Laws 2014, item 516), outdoor pesticides can be applied using:

- ground equipment at a distance of at least 20 m from the apiaries;
- field sprayers at a distance of at least 3 m from the edge of the roadway of public roads, excluding public roads falling within the category of municipal and district roads;
- field sprayers at a distance of at least 1 m from reservoirs and watercourses and non-agricultural areas other than those treated with plant protection products.

When using plant protection products, the label of the products should be read in detail, as it may contain additional conditions limiting their applicability.

In accordance with the legislation in force, any use of the plant protection product must be registered. Professional users are obliged to maintain and store for three years documentation containing the name of the plant protection product, the time of use and the dose applied, the area or surface area or unit of weight of the grain and crop or the facilities on which the plant protection product has been applied. Legislation also requires the method of fulfilling the requirements of integrated plant protection to be indicated in the documentation by providing at least the reason for treatment with a plant protection product. Filling out the IP Notebook, mandatory under the integrated plant production

scheme, fulfils the requirement to keep the above-mentioned documentation for certified crops.

For treatment with plant protection products, equipment intended for that purpose shall be used which, when used for its intended purpose, does not present a risk to human health, animal health or the environment and is technically efficient and calibrated to ensure the correct application of plant protection products. The holders of equipment for the use of plant protection products are obliged to carry out periodic tests confirming its good technical condition. The first inspection of a new sprayer is conducted no later than five years from the date of its purchase. Tractor and self-propelled field sprayers should be tested at intervals of no more than three years. Manual and backpack sprayers whose tank capacity does not exceed 30 litres are excluded from the testing obligation.

2.2. Integrated plant production in legislation

Under this integrated plant production certification scheme, all legal requirements for plant protection products must be respected, with particular regard to the principles of integrated plant protection.

2.3. Certification rules

The basic requirement for the possibility of growing crops in the system of integrated plant production and obtaining an IP certificate is to submit a notification to the entity certifying integrated plant production.

The notification of the intention to use integrated plant production shall be made annually by the plant producer concerned to the certification body, **within the time limit laid down in Article 55(2) of the Plant Protection Products Act of 8 March 2013.** The integrated plant production scheme is open to all producers. Notification of the intention to participate in the system is possible in paper form by post, in electronic form, and directly.

Integrated production training is generally available, and those who have acquired the appropriate knowledge through education (confirmed by a post-primary school or higher education) are exempt from the obligation to complete basic training.

Following the notification, the agricultural producer is obliged to cultivate crops according to the method of integrated plant production for the notified plant and to document their actions in the IP Notebook in detail. A model notebook is included in the Regulation of the Minister for Agriculture and Rural Development of 24 June 2013 (consolidated text: 7 November 2023) on documenting activities related to integrated plant production (Journal of Laws of 2023, item 2501).

The certification body inspects growers who follow the principles of integrated plant production. Supervisory actions cover in particular:

- completion of IP training;
- compliance with the production methods approved by the Main Inspector for Plant Health and Seed Inspection;
- fertilisation;

- documentation;
- following hygiene and health principles;
- collection of samples and control of highest tolerable plant protection product residues as well as of nitrate, nitrite and heavy metal levels in plants and plant products.

The maximum permissible plant protection product residue content and nitrate, nitrite and heavy metal levels in plants are tested in the plants or plant products of no less than 20% of the plant producers listed in the plant producer register held by the certification body, starting with any plant producers suspected of not following integrated plant production principles. The tests are carried out in laboratories properly accredited in keeping with the provisions of the Act of 30 August 2002 on the conformity assessment system or the provisions of Regulation No 765/2008.

A certificate issued at the request of the grower attests that integrated plant production principles are followed. In order to obtain the certificate, the producer must:

- have completed an integrated production plant training and holds a corresponding training certificate, subject to Article 64(4),(5),(7) and (8) of the Act on plant protection products;
- grow and protects plants in line with the detailed methodology approved by the Main Inspector available on the website administered by the Main Inspectorate of Plant Health and Seed Inspection;
- use fertilisation based on the actual plant nutritional needs determined on the basis of, in particular, the analysis of the soil and plants;
- correctly document the activities related to integrated plant production;
- follow plant production hygiene and health rules, in particular those referred to in the methodology;
- ensure that no maximum permissible residues of plant protection products and levels of nitrates, nitrites, and heavy metals have been exceeded in plant and plant product samples collected for testing;
- adhere to requirements concerning plant protection against harmful organisms, particularly those specified in the methodologies, during plant production.

Integrated plant production certificates are issued for the period necessary for the plant product to be disposed of, but for no longer than 12 months.

Growers who have been granted a certificate attesting that they follow integrated plant production principles may use the Integrated Plant Production mark to distinguish the plants for which the certificate has been issued. The model of the mark is made available by the Main Inspector on the website administered by the Main Inspectorate of Plant Health and Seed Inspection.

3. CLIMATE AND SOIL REQUIREMENTS AND SITE SELECTION

3.1. Climate

All mustard species have low thermal requirements and tolerate spring frost well, going up to –6 °C. They produce high yields in the growing seasons at moderate temperatures. They have high water requirements, but they are less sensitive to drought than spring rapeseed. They yield best in areas where the total rainfall from April to September is at least 400 mm. They require good humidity of the soil during emergence. They need the most water from the stage of the inflorescence shoot elongation to the stage of seed formation. Drought during this period has the effect of significantly reducing the yield. Water deficit during ripening is critical in terms of the fat content of the seeds. Thanks to the most developed root system, white mustard is the least sensitive to temporary water shortages, and it can be grown across the country, regardless of the climatic conditions. The cultivation of brown and black mustard should be limited to the areas suitable for spring rape (Muśnicki 1999).

3.2. Soil

Mustards are best suited to be grown on calcium-rich clay and sandy clay soils, as well as low peats and sapric with regulated groundwater levels. They require a neutral pH. They have lower soil requirements than rapeseed and can be grown on lighter soils. Grown for seeds, they produce the highest yields on the soils of wheat categories and ‘rye: good’ category. They do not tolerate acidified, impermeable and wet soils. Black mustard has the greatest soil requirements, which should be grown on wheat/beet soils. Requirements of brown mustard are lower, and those of white mustard lowest.

3.3. Precursor crops

The best precursor crop for all mustard species are potatoes on manure, lucerne, clover and mix of cereals and legumes. Cereals are a good precursor crop, especially on better soils. Mustard should not be grown after sunflower, poppy and flax. Rapeseed is also an equally bad precursor crop, because growing mustard seeds after brassica plants increases the likelihood of a serious disease such as clubroot, hence the need to maintain at least a 3-year interval between their cultivation at the same site. In addition, when nitrogen is applied to rapeseed plantations in pre-spring, intensive mustard vegetation development and longer flowering and delayed seed formation should be expected. Mustards also do not tolerate being grown one after another (Toboła 2010).

4. SELECTION OF MUSTARD VARIETIES IN INTEGRATED PRODUCTION

White mustard varieties can be widely used; they are grown on their own for seeds, used in fodder mixtures, are sometimes used as support plants, and are usually sown in stubble catch crops for green fertilizer or mulch (Nowakowski 2013; Sawicka and Kotiuk 2007).

Taking into account the botanical and functional characteristics of mustard varieties, the cultivation of mustard varieties should be considered to be an important element meeting the requirements of integrated plant production.

The seeds are spherical, predominantly yellow and yellow-beige, with a mass of thousand seeds of 6–10 g. They contain 25–30 % fat and 27–35 % protein (45–48 % in non-fat dry matter) and glucosinolates, including mainly synalbin. In the presence of water and under the influence of the enzyme myrosinase, mustard oils are secreted, which have a sharp, burning taste. The seeds are mainly used in the food industry. Whole or crushed, they are used as a aromatic spice and as a preservative. Mostly, however, they are the main raw material for the production of mustard. In addition, seeds are widely used in the pharmaceutical industry and in medicine, especially traditional medicine. Cold pressed oil is used to a small extent for food purposes, more often in pharmaceuticals and the cosmetics industry, and extracted oil is used for technical purposes. After-extraction meal and marc of the varieties containing a large amount of glucosinolates are not used as a component of animal feed.

Mustard seed of the varieties entered in the national register, the corresponding registers of Member States other than the Republic of Poland or the Community catalogue may be marketed.

The list of varieties registered in the registry can be found on the RCFCT website, at the following link: https://coboru.gov.pl/pl/kr/kr_gat. The results of the tests and other information on the varieties examined are published in the RCFCT publications, e.g. the 'Descriptive List of Agricultural Plant Varieties'. There are currently more than 230 white mustard varieties in the Common Catalogue of Varieties of Agricultural Plants (CCA). Most of the varieties registered in the registry are suitable for cultivation both in the main crop for seeds and in stubble catch crops. Varieties differ in yield and chemical composition of the seeds, as well as the main agricultural and utilitarian characteristics such as the time of emergence, plant height, resistance to lodging and diseases, including the possibility of reducing the abundance of beet cyst eelworm in the soil. All these characteristics should be taken into account by the grower when choosing the variety for cultivation in an integrated production system.

The traditional varieties of white mustard contain a large amount of glucosinolates (approximately 180–200 µM/g seeds) in the seeds, mainly sinalbin, i.e. specific compounds from the glucoside group containing sulphur. On the other hand, the oil obtained from seeds contains an excessive amount of undesirable erucic acid (approx. 40–45 %). Seeds of such varieties are used primarily for seasoning and pharmaceutical purposes. In recent years in Poland, breeders have managed to produce varieties with a changed chemical composition of the seeds. These varieties are characterised by a low content of erucic acid in seeds and a low content of glucosinolates. The composition of the oil from these seeds is similar to that of double-rectified '00' rapeseed oil and is therefore universal, suitable for food and technical purposes.

In the experiments with varietals of white mustard in seed cultivation, seed yields of 18.7 dt per ha were collected on average over the years of the tests, with a variation of between 17.3 and 20.4 dt per ha over the years. The growing season for the varieties, from the emergence to technical maturity, lasted an average of 105 days.

White mustard is the most common species grown in stubble catch crops. Plants grow quickly, and their growth period is relatively short; they produce a large vegetative mass, shade the soil well, limiting the growth of weeds and withstand short-term frosts quite well. Mustard varieties may be grown after plants that leave the field somewhat later, mainly cereals. They then fulfil their phytosanitary role, reducing the risk of over-accumulation of pathogens and pests of these plants. Plants of varieties intended for green fertiliser should be ploughed. The dry matter introduced into the soil in this way enriches it with organic matter, and the mineralisation processes that take place make nutrients available for the follow-on plant. Catch crop cultivation of mustard varieties also improves the physical, chemical and biological properties of the soil. It is also beneficial to leave the grown plant mass for the winter in the form of mulch, which is ploughed in early spring or sown with the main plant without tillage. In experiments with varieties of white mustard grown in stubble catch crop, yields of fresh matter of 161 dt per ha and 30.4 dt per ha of dry matter were collected on average over two years of testing. The length of the growth period from the emergence to the beginning of flowering of the plants was on average 42 days.
White mustard varieties, compared to spring rapeseed, show greater resistance to diseases, are less likely to be damaged by pests, are less sensitive to dry conditions and can be grown on lighter soils. In crop rotation with rapeseed, mustard should not be grown, as possible volunteer seeds can reduce the quality of the crop, and the plants are hosts to many of the same disease vectors, e.g. clubroot (*Plasmodiophora brassicae)*, and pests.

White mustard varieties are evaluated favourably in crop rotation also because of their anti-eelworm properties, which should be used for biological control of nematodes. Most of the registered varieties of white mustard have the property of reducing the population of beet cyst eelworm *(Heterodera schachtii* Schmidt) in the soil (usually by about 30–40 %). Only the oldest varieties, grown mainly for seed cultivation, do not have these characteristics. On the contrary, they may increase the prevalence of pests in the field in which they have grown. When choosing a variety for cultivation, it is always worth checking with the seed distributor whether the variety has the property of reducing the abundance of beet cyst eelworm in the soil. Decreasing the number of nematodes in the soil is more effective in the cultivation of mustard seed as the main crop than in short-term catch crop cultivation. The benefits of growing varieties that help combat beet cyst eelworm can best be achieved in crop rotation with beets.

White mustard is the most fertile of the mustards grown in our country, the least demanding, and what is important, cultivated varieties are characterised by high reliability and stability of yield. It is also one of the plants that are most tolerant to dry conditions. The varieties are also beneficial for pollinators. Plants freely flown over by pollinators form more husks and seeds in the husks, and this results in a significant increase in seed yield (up to

70 %). The allelopathic effect of white mustard, especially its roots, on other plants has also been shown, which is associated with the presence of glucosinolates in them. These compounds, inter alia, perform defensive and protective functions against pests and competing species.

Brown mustard is cultivated locally in Poland on a very small area. It requires better humidity conditions than white mustard. The seeds are mostly brown in colour (there are also varieties with light yellow seeds) and are quite small (2 to 2.5 g per thousand seeds). They contain about 35 % fat and about 28 % protein and the characteristic glucosinolate: sinigrin (0.8–0.9 %). They are mainly used as a spice and in medicine. Oil is used in the food industry, including in the manufacture of cosmetics and medicines. The marc is used to make the 'sarepska' mustard.

Black mustard is grown in Poland only sporadically and only in some parts of the country. It has relatively high humidity requirements. The seeds are brown in colour, often with a reddish tint and a whitish coating, and are fine (1.5–2.5 g per thousand seeds). They contain more than 30 % fat and about 27 % protein and the same glucosinolate as in brown mustard: sinigrin (0.5–0.8 %). It is the least fertile and grown primarily as a medicinal and spice plant.

Detailed information on the selection of varieties recommended for IP by the RCFCT can be found in the list at: coboru.gov.pl/pdo/ipr.

5. PRE-SOWING TILLAGE AND SOWING

5.1. Soil cultivation

Mustard is cultivated on soil ploughed in autumn. After the early precursor crops, the field is ploughed and harrowed. If weeds appear, repeated tillage should be performed. The pre-winter ploughing should be carried out at a depth of not less than 20–22 cm. After late precursor crops such as potatoes and stubble catch crops, the autumn cultivation is limited to pre-winter ploughing.

Spring works begin after drying the tops of the skids. On lighter soils, the field is worked with a levelling plate, and on heavier ones with a harrow. For pre-sowing, a cultivator or harrows coupled to a string roller or aggregates equipped with two sections of shafts — front and rear — are used. The depth of pre-sowing cultivation should be slightly higher than the depth of sowing.

Mustard cultivation is simplified by leaving a stubble catch crop for mulch until spring. In this case, the cultivation consists in cutting and mixing crop residues with the soil to a depth of 10–15 cm. Weeds that overgrow the mulch should be destroyed with a complete-action herbicide before sowing mustard. California bluebell is considered to be the best catch crop used as a mulch for mustards, and it is characterised by a fast growth rate and a vegetal mass that is not highly lignified.

Cultivation of catch crops in which only white mustard is of practical importance is reduced to a shallow plough covering the stubble or a plough-free crushing of the soil without turning it. On light soils, ploughing or discing is carried out to a depth of up to 10 cm, and on heavier soils, to a depth of 14–16 cm. The plough should be aggregated with the Campella shaft or a special shaft. In order to ensure early and full emergence, all treatments should be performed carefully (Toboła 2010).

5.2. Sowing

Mustard should be sown as early as possible, but the soil should be heated and dried. Due to their strong photo-periodic reaction and sensitivity to drought, early sowing has a positive effect on development and results in high yields. White mustard, the date of sowing of which falls at the beginning of sowing of spring cereals, is sown the earliest. The sowing of brown and black mustard should be completed at the end of the sowing of spring cereals. When cultivating white mustard in catch crops, it is necessary to delay sowing until 10–15 August, because if sown earlier, it quickly blooms and produces little green mass.

In order to ensure an optimal plant density of 100–150 per 1 m^2 for white mustard and 150–200 plants per 1 m^2 for brown and black mustard, the sowing quantity for white mustard (with the mass of a thousand seeds of 7 g) is 8–12 kg/ha, and for brown and black mustard (with the mass of a thousand seeds of 2.5 g) is 4.5–6 kg/ha. When grown as a catch crop, the sowing quantity of white mustard increases to 18–20 kg. Grown with California bluebell or with California bluebell and buckwheat, it is sown in the following amount of seeds:

- 10–12 kg of mustard + 3–4 kg of bluebell;
- 8–10 kg of mustard + 40–50 kg of buckwheat + 3–4 kg of bluebell.

Mustard is sown in a narrow-row spacing: 12–15 cm, narrowed-row spacing: 20–25 cm or wide-row spacing: 30–40 cm. The clustered character of brown mustard makes sowing in a narrow-row spacing best for this species. A more expansive white mustard is sown in narrowed rows. Black mustard, on the other hand, should be sown in a wide-row spacing, suitable for mechanical weed control. When cultivating white mustard as a catch crop, it is sown at a row distance of 12–15 cm.

Mustard is sown at a depth of 1–2 cm. Only on very dry sites, white mustard seeds can be sown deeper, at 2.5–3 cm.

6. SUSTAINABLE MUSTARD FERTILISATION SYSTEM

In integrated production, fertilisation is determined on the basis of a nutrient balance analysis before each crop, and soil testing is conducted at least every four years (and documented).

In mustard cultivation, as for most crops, the most significant factor is the location where the crop is to be grown, especially the pH of the soil. This parameter has a significant

impact on the availability of nutrients contained in the soil, which are supplied in the form of mineral fertilisers. The most optimal pH for mustard is between 5.8 and 6.8, at which plants make the most efficient use of nutrients. Soil resources and minerals contained in them are best used by white mustard, and the least by black mustard. All mustard varieties, despite their different yields, show a fairly similar demand for individual nutrients. It is usually 40–80 kg/ha nitrogen (N), 30–60 kg/ha phosphorus (P_2O_5), 60–100 kg/ha potassium (K_2O) (Table 1). Other macro- and micro-elements should be additionally used in the form of foliar fertilisers, using a field sprayer. The doses of individual ingredients should be applied taking into account whether manure has been applied to the growing site. Depending on this, doses are increased (lack of manure) or decreased (with manure) as appropriate. In the case of heavier soils, phosphorus-potassium fertilisation can be applied in autumn for ploughing or spring, while in the case of lighter soils, in spring after levelling the field before spring cultivation (Budzyński and Zając 2010).

Table 1. Demand for mustard minerals

Site	Nutrients [kg/ha]		
	N	P_2O_5	K_2O
With manure	40	30	60
No manure	80	60	100
Site as a stubble aftercrop	40-80	30-50	30-70

The most effective forms of nitrogen are calcium-ammonium nitrate or ammonium nitrate. If use of higher nitrogen doses is planned, they should be applied in two stages. Pre-sowing using 2/3 of the intended dose and 1/3 thereof as top dressing, where the second dose is applied about two weeks after mustard emergence to the phase of flower shoot elongation. In the case of mustard nitrogen feeding, foliar application is also recommended in two phases. The first one when plants reach about 15 cm in height, and the second one during the green bud phase. Attention should be paid to the amount of nitrogen used together, as this may result in undesirable effects in the form of overgrown plants, which may lead to their lodging and significant severity of infestation by diseases. In the case of nitrogen overdose in mustard, the ripening period of seeds may also be prolonged (Paszkiewicz-Jasińska 2005). An important aspect in the cultivation of white mustard is also the fact that it also shows a high demand for sulphur, magnesium and boron. In addition, when growing mustard, liming is necessary in the case of acidic soils, which is applied immediately after the pre-cropping has been harvested. On light and moderately compact soils, the dose of lime in the form of carbonate ($CaCO_3$) or magnesium carbonate ($CaCO_3$ + $MgCO_3$) is 2–3 t/ha. In heavy and compact soils, the dose is 1.0–1.5 t/ha in the form of calcium oxide (CaO).

The Integrated Plant Production scheme prohibits the use of sewage and digestate sludge and other fertilisers of unknown composition for fertilising purposes due to the risk of introducing unmonitored hazardous substances into the secondary circulation, which can be accumulated in the process of their manufacture.

7. INTEGRATED PROTECTION AGAINST PESTS

Integrated production (IP) of mustard should be carried out using integrated pest management and using technical and biological progress in cultivation and fertilisation with particular regard to human and animal health and environmental protection.

Integrated pest management includes all available actions and methods of protection against harmful organisms (weeds, pathogens, pests) with preference given to the use of non-chemical measures and methods that reduce their harmfulness, in particular:

- the use of crop rotation, the appropriate date for sowing and plant density;
- the use of appropriate agronomics, including the use of mechanical plant protection;
- the adoption of appropriate measures and methods for the protection of plants against pests should be preceded by the monitoring of their presence and take into account current knowledge on the protection of plants against pests;
- the use of seed satisfying the requirements of production and quality in accordance with the provisions on seeding;
- the application of fertilisation and liming, where appropriate;
- the use of hygiene measures (cleaning, disinfection) to prevent the occurrence and spread of pests;
- protection of beneficial organisms and creating favourable conditions for their occurrence, in particular for pollinators and natural enemies of harmful organisms.

In the framework of integrated plant protection, when carrying out a chemical plant protection treatment, account should be taken of:

- the appropriate selection of plant protection products in such a way as to minimise the negative impact of plant protection treatments on non-target organisms, in particular pollinators and natural enemies of harmful organisms;
- limiting the number of treatments and the quantity of plant protection products used to a necessary minimum;
- preventing the formation of resistance of harmful organisms to plant protection products by appropriate selection and their alternating use;

plant protection products authorised for use in European Union countries are subject to periodic review in accordance with the latest studies and principles set out by the European Union. Strict requirements in terms of their quality, toxicology and effects on arable crops and the environment are monitored so that they do not pose a risk to the user, the consumer and the environment.

The current mustard protection programme may be used when planning the use of plant protection products.

The list of plant protection products authorised in Poland is published in the register of plant protection products. Information on the extent of pesticide use in particular crops is placed on the labels. A plant protection product search engine provides help in the selection

of pesticide (https://www.gov.pl/web/rolnictwo/wyszukiwarka-srodkow-ochrony-roslin---zastosowanie). Current information on plant protection products use is available on the Ministry of Agriculture and Rural Development website at: https://www.gov.pl/web/rolnictwo/ochrona-roslin.

The list of plant protection products authorised for IP is available on the Online Pest Signalling Platform at: https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.html.

For protection against harmful organisms (weeds, pathogens, pests), only products registered and authorised for marketing and use in Poland may be used which are clearly indicated on the labels attached to the packaging that they are recommended for use in mustard cultivation.

The products must be used in a way that ensures that human, animal or environmental health is not endangered.

It should be borne in mind that the products included in the protection programme do not present a risk when properly applied in accordance with the approved labelling of the plant protection product. Observing application recommendations such as: appropriate selection of product, dose, date of application, appropriate stages of development of crop and pests, appropriate thermal and humidity conditions, and technical conditions for the procedure have a decisive impact on the safety of treatments with plant protection products.

In order to perform laboratory diagnostics (most often to identify disease vectors), tests are carried out in laboratories that are appropriately accredited.

7.1. WEED INFESTATION CONTROL

7.1.1. The most important weed species

Mustard cultivation is threatened by many species of weeds. The state of weed infestation depends mainly on the composition and abundance of the soil seed bank. Mustard is infested by both monocotyledonous and dicotyledonous weeds. The most dangerous dicotyledonous weeds are: white goosefoot, false mayweed (formerly scentless mayweed), catchweed, common chamomile, field chamomile and field bugloss. Dicotyledonous weeds that pose less risk include: cornflower, purple and henbit dead-nettle, wild buckwheat, buckwheat, speedwells, shepherd's purse, field penycress and field pansy. Dicotyledonous weeds that may be present in mustard cultivation are common fumitory and hemp-nettles. Their negative impact is limited, as they do not occur en masse in mustard cultivation. It should be borne in mind, however, that growing plants will freely form seeds, from which another generation of weeds will grow in the following years, threatening the succeeding plants. Perennial weeds, such as common mugwort, field thistle and field bindweed, are increasingly present in mustard. The increasing prevalence of perennial

weeds is associated with the simplifications in the cultivation of land. Monocotyledonous weeds threatening mustard cultivation are: couch grass (perennial weed), self-seeding cereals (if mustard was grown after cereals), as well as, to a lesser extent, barnyard grass. Even a basic knowledge of weed characteristics is of great importance for conducting field inspection, on the basis of which a programme of weed control in mustard cultivation should be established (Table 2) (Paradowski 2013, 2015).

The threat posed by weeds in the cultivation of mustard depends strongly on the species of mustard grown. In the cultivation of white mustard, the weed infestation is definitely weaker than in the case of brown and black mustard. This is due to the fact that white mustard is grown on weaker soils, where most often the spectrum of weeds is smaller, and their development is less lush. In addition, white mustard is a more branching plant compared to other mustard species. This makes white mustard compete more strongly with weeds, thus limiting their growth. An advantageous factor in mustard cultivation, that significantly increases its competition with weeds, is early sowing and its early emergence and resistance to frosts (Jajor et al. 2017).

Table 2. Characteristics of weeds most commonly found in mustard cultivation

English name	Latin name	Characterisation
Small-flowered crane's bill	*Geranium pusillum*	spring species, preferring moist, humus-rich soils rich in lime and nitrogen; weed dangerous in case of mass occurrence during mustard emergence; it can produce several generations during one growing season
Common mugwort	*Artemisia vulgaris*	perennial species, prefers fertile soils, rich in nitrogen; due to its strong growth, it competes with mustard
Cornflower	*Centaurea cyanus*	annual species, commonly found on all types of soil, but prefers light, sandy and sandy loam; under favourable conditions it grows up to 1 m in height
Common fumitory	*Fumaria officinalis*	annual species, prefers moist, humus, airy soils and soils rich in nitrogen and lime; dangerous for mustard during mass emergence
Cockspur	*Echinochloa crusgalli*	annual, thermophilic species, prefers moist soils rich in nitrogen and calcium; threatens mustard plantation, which in the initial period of vegetation grows more weakly
Field bugloss	*Anchusa arvensis*	spring species growing nesting, showing strong competition with the crop; prefers acidic light soils
Field pansy	*Viola arvensis*	annual species, widespread throughout the country; dangerous due to abundant occurrence during mustard emergence
Common chickweed	*Stellaria Media*	spring species, common throughout the country, favours humus soils, moist nitrogen-rich soils; it forms a strong turfing that significantly interferes with the emergence and development of mustard;
Field mustard	*Sinapis arvensis*	annual species, prefers fertile soils rich in lime; the harmfulness of this species is not only limited to competitiveness, but is also a host plant for many diseases and pests, e.g. for clubroot pathogens
Purple dead-	*Lamium*	spring species, prefers fertile clay soils; threatens many crops,

nettle	*purpureum*	including mustard
Henbit dead-nettle	*Lamium amplexicaule*	spring species, occurs on different types of soils; negatively affects the growth of various crops, including mustard
Goosefoot	*Chenopodium album*	annual species, commonly found throughout the country, prefers loose soils, rich in nitrogen and potassium; seriously threatens mustard cultivation
False mayweed	*Matricaria maritima* subsp. *inodora*	annual species, occurs on different types of soils, but prefers humus and moist soils; in mustard cultivation it can reach up to 1 m in height
Field thistle	*Cirsium arvense*	perennial species, occurs on different types of soil, prefers soils with regulated water-air relations, rich in nutrients; difficult to control, often occurs in clusters
Couch grass	*Agropyron repens*	perennial, monocotyledonous; occurs on all types of soils; highly competitive, rapidly spreading through runners
Common hemp-nettle	*Galeopsis tetrahit*	annual species, prefers clayey and lighter humus soils with a high level of groundwater; competitive with mustard during mass emergence
Speedwell	*Veronica* spp.	species threatening mustard cultivation during mass emergence
Catchweed	*Galium aparine*	annual species, prefers moist, fertile, nitrogen-rich soils; the nuisance of this weed outside competition is due to the difficulty of cleaning mustard seed from catchweed seeds
Wild radish	*Raphanus raphanistrum*	annual species, prefers sandy, loamy and slightly acidic soils; the harmfulness of this weed is mainly due to competition; host of many diseases and pests, including clubroot
Shepherd's purse	*Capsella bursapastoris*	annual species, occurs on various types of soil; prefers fertile, humus, loose and airy soils; poses a serious threat to mustard cultivation during mass emergence; host to many diseases and pests, including clubroot
Field pennycress	*Thlaspi arvense*	annual species, commonly found throughout the country, prefers clay soils, medium and heavy, rich in nutrients and calcium; poses serious threat to mustard cultivation during mass emergence; host to many diseases and pests, including the vector of clubroot

7.1.2. Non-chemical methods for regulating weed

Mechanical weed control should start immediately after harvesting of the precursor crop (Jajor et al. 2017). During this period, post-harvest tillage is carried out. The cultivation schedule and the tools used to break the stubble and manage crop residues depend to a large extent on the farm's machine park, as well as the weeds present in the field. A sub-tillage plough, a disc harrow or a stubble cultivator may be used for post-harvest cultivation. Until recently, ploughing was the primary treatment for post-harvest cultivation; currently it is used to a lesser extent. The lower popularity of ploughing is due to its low efficiency and the need to carry out harrowing, which significantly increases costs. Therefore, it has been replaced by tools characterised by greater efficiency, which makes them less labour- and energy-intensive. These tools include disc harrows and a stubble cultivator. These tools should not be used if couch grass and other perennial weeds are present in the field. This is due to the fact that these tools are equipped with cutting elements. Their use causes

fragmentation of the vegetative propagation organs, which significantly increases their spread in the field and, consequently, pressure and competitiveness for mustard. When mechanically combating weeds in post-harvest cultivation, it should be remembered to carry out the cultivation carefully and after successive weed emergences. This significantly reduces the number of weeds endangering the crop. The next element is the performance of winter ploughing. In the spring, after drying of the skids, as soon as one can enter the field, a levelling plate or harrow should be used. Cultivation with these tools accelerates the heating of the soil, reduces evaporation, and also creates favourable conditions for the germination of weeds. They can be successfully combated by performing harrowing once or twice.
Mustard can be grown successfully in different spacing of rows.

- narrow-row — 12–15 cm;
- narrowed-row — 20–25 cm;
- wide-row — 30–40 cm.

Thus it is possible to perform mechanical weed control without problems. One of the most commonly used treatments, irrespective of the spacing of the rows and the mustard species grown, is harrowing. This treatment is performed in the initial period of germination of mustard seeds with simultaneous emergence of weeds. During this period, light harrows or weeder harrows should be used. When growing mustard in a narrow and wide spacing, one or two weeding between the rows should be carried out. The weeding should be carried out until the inter-rows are covered. Therefore, when necessary, a third mechanical weed control procedure can be performed. This situation most often occurs in sites with poor soil structure. Narrow-row cultivation and early mustard sowing mean that it is not always necessary to undertake mechanical fight against weeds. Particularly in the case of the cultivation of fast-growing species, which include brown mustard and black mustard. Increasingly, in order to reduce weed infestation, mustard is sown onto the mulch.

7.1.3. Chemical methods of weed infestation control

The basic condition for effective control of weeds in mustard cultivation is the correct recognition of weeds, both mono- and dicotyledon ones (Paradjowski 2013). Another very important factor for the effective control of weeds is the selection of the herbicide, or more precisely, the active substance. The current state of weed infestation should be strictly followed when selecting the active substance. Where soil herbicides are used, the choice of active substance dedicated to controlling weeds in mustard must be made on the basis of an evaluation of the weed infestation status of the crops grown in the previous growing season. When choosing an active substance, it is important to remember to use substances with a different mode of action than those used in the previous growing season, if possible. This helps to prevent the occurrence of weed resistance. When using chemical weed control, care must be taken to ensure that the treatment is carried out in a timely and diligent manner. When applying herbicides to soil, it should be borne in mind that soil moisture significantly affects herbicide effectiveness and crop safety. When the soil is too dry, the

effect of herbicides applied to the soil is limited, as their effectiveness may be lower, often insufficient. In such a case, it may be necessary to re-treat the plant with a foliar herbicide. On the other hand, when the soil is excessively humid, the active substance may be moved to the area of germinated seeds, which creates a risk of damage to the crop. When applying foliar herbicides, care should be taken in order to apply to dry plants and when the wind speed is less than 4 m/s.

Methods for determining weed abundance and damage thresholds

All mustard species are considered minor plants as they are not sown on a large area. In the case of white mustard, it is worth knowing how to recognize weeds in the phase of 2 to 6 leaves. This is a phenological term for the use of herbicides in this mustard.

Decision support systems

Decisions can only be supported by the Plant Protection Institute — State Research Institute in Poznań or other scientific and research units dealing with plant protection issues. Expert opinions in support of decisions must be drawn up on the basis of the results of research carried out in scientific and research units covering also the protection of minor plants.

The list of plant protection products authorised in Poland is published in the register of plant protection products. Information about the scope of their use for particular crops is contained on the product's label. When using plant protection products, it is important to remember to strictly follow the recommendations included in the labels. A repository of plant protection products can help to choose a herbicide for mustard cultivation. Current information on plant protection products use is available on the Ministry of Agriculture and Rural Development website at: https://www.gov.pl/web/rolnictwo/ochrona-roslin.

The list of plant protection products authorised for IP is available on the Online Pest Signalling Platform at: https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.html.

7.2. REDUCTION OF DISEASE VECTORS

7.2.1. The most important diseases

Mustard can be infested by several pathogens that also occur on other plant species, mainly spring and winter rapeseed (Jasińska and Kotecki 2003; Budzyński and Zając 2010). Due to, among other things, the rapid growth of plants and a much shorter vegetation period than in the case of winter oilseed rape, mustard does not usually suffer from a high intensity disease infestation. Nevertheless, on the plantations of this plant, one can already observe diseases with an economic impact such as: clubroot, black spot, as well as seedling

blight, Sclerotinia sclerotiorum, grey mould, white rust and others. The increase in the importance of clubroot in recent years is associated with the frequent cultivation of winter rapeseed and other brassicas, e.g. mustard (catch crops), turnip rape, spring rapeseed, vegetables from the same family on the same site (Korbas et al. 2008). This disease causes very significant losses in seed yield, and in addition, there is a gradual accumulation of infectious material in the soil. In some areas this limits the areas under cultivation of the species listed.

The magnitude of the losses caused by the pathogens depends on the area where the crop is grown, the precursor crops, the weather patterns during the season and the development phase of the plant in which the infection occurs. Mustard diseases are caused by one or more pathogens and their indicative significance and potential sources of infection can be found in Table 3.

Table 3. Economic significance of selected mustard pathogens in Poland

Disease (cause)	Potential threat	Sources of infection
White rust (*Albugo candida*)	++	self-sown seeds, weeds of the brassica family, seeds
Cabbage black leaf spot *Alternaria* spp.	+++	seeds, crop residues, weeds
Clubroot on mustard (*Plasmodiophora brassicae*)	+++ (locally)	spores in soil; manure, if animals have been fed infested plants; contaminated tools, machinery, water, weeds and self-sown seeds
Powdery mildew (*Erysiphe cruciferacum*, *Erysiphe polygoni*)	+	weeds, self-sown seeds
Downy mildew of crucifers (*Hyaloperonospora parasitica*)	+	crop residues, self-sown seeds,
Dry rot of mustard (*Leptosphaeria maculans*, formerly *Phoma lingam*)	+	crop residues, self-sown seeds, seeds
Grey mould (*Botryotinia fuckeliana*, formerly *Botrytis cinerea*)	+	crop residues, self-sown seeds, weeds, seeds, soil
Fungal rot (*Sclerotinia sclerotiorum*)	++	sclerotia (endospores) in the soil and in the seed; infested plant residues
Seedling blight (*Pythium debaryanum*, *Rhizoctonia solani*, *Alternaria* spp., *Phoma lingam*, *Fusarium* spp. and others)	++	soil, seeds

+ small ++ medium +++ large

According to Kryczyński and Weber (2011); Jajor et al. (2017)

Proper diagnosis of the diseases is a necessary step in the integrated production of plants. Symptoms of infestation by pathogens can be observed throughout the growing season, on all plant organs from the roots, through shoots and leaves, to flowers and husks (Table 4). It is not uncommon that several different spots are observed on one plant or even its organ; it may be associated with, among other things, the so-called mixed infection, i.e. an infestation by several pathogens at the same time or changes caused by abiotic factors. For ease of identification, the last column lists factors that may cause symptoms similar to those described. In integrated production, systematic monitoring of the occurrence of diseases from the time of emergence to the beginning of maturation, at least once a week, is necessary. It should also be borne in mind that the clubroot pathogen causes characteristic symptoms on the roots and therefore the plants should be gently dug out to detect the disease.

Table 4. Diagnostic properties of mustard diseases

Disease	Diagnostic features	Possible confusion of symptoms with another disease or agent
White rust	**Leaves** — white, vesicular lesions (pathogen structures) appear on the underside of the leaves. Initially small, then covering more and more areas of the tissue. On the top of the leaves, at the site of the appearance of white lesions, chlorotic discoulorations form. **Stem** — white, vesicular lesions (pathogenic structures). Growth is inhibited and the shoots are distorted (crooked). **Inflorescence** — white, vesicular lesions (pathogen structures). Inflorescences are distorted and often become crooked.	powdery mildew of brassica, dry rot of mustard, grey mould, cabbage black leaf spot
Cabbage black leaf spot	**Seedling** — brown oval patches on cotyledons, narrowing of the root neck and black spots on the sub-leaf of the stem. As a result of the infection, the plants die off (seedling blight). **Leaves** — concave spots ranging from light brown to black in colour with a chlorotic areola. Concentric zoning is often present on larger spots. The spots gradually merge. **Stem** — elongated, black or pale grey spots with clearly marked edges. **Husks** — oval or oblong concave spots brown or black in colour, causing distortion of the husks and their premature cracking.	powdery mildew of brassica, dry rot of mustard, grey mould
Clubroot on mustard	**Root** — initially bright, hard growths of varying shape and size, which then darken and disintegrate. Changes occur on the main root, lateral roots and sometimes also on the root neck. **Leaves** — yellow or beetroot in colour, gradually wither and their growth is inhibited (non-specific symptoms). **Stem** —wilting and inhibition of growth. Accelerated budding and flowering (non-specific symptoms) may occur.	seedling blight, turnip gall weevil; nutritional deficiency
Powdery mildew	**Leaves** — oval patches of white, floury coating (pathogen mycelium), which gradually grow over the entire surface of the leaf. Leaves turn yellow and die.	grey mould, dry rot of mustard

	Stem — oval patches of white, floury coating (pathogen mycelium), which gradually grow over the entire surface of the stem. Brown and purple spots often appear under the coating. **Husks** — oval patches of white, floury coating (pathogen mycelium), which gradually grow over the entire surface of the husk.	
Downy mildew of crucifers	**Seedlings** — a delicate, greyish coating (pathogen mycelium) appearing on the lower side of the cotyledon. The plants turn yellow and then die off. **Leaves** — a delicate, greyish coating (pathogen mycelium) appearing on the underleaf; on the upper side of the leaf (at the site of the appearance of the coating) yellow irregular spots with a brown or black border. Leaves turn yellow and die off. Distorted inflorescences appear on the plant. The plant does not produce husks or seeds.	dry rot of mustard, grey mould, cabbage black leaf spot, white rust
Dry rot of mustard	**Seedling** — oval, brown necrosis, narrowing of the root neck or part of the root. As a result of the infection, the plants die off (seedling blight). **Leaves** — small, yellow discolourations that enlarge to form oval, light brown, beige or grey necroses often surrounded by a yellow (chlorotic) border. Clusters of pycnidia (black, spherical points) visible on the surface of the spots. **Stem** — oblong, extensive, light brown spots surrounded by a brown-red border. On the surface of the spots, clusters of pycnidia are visible. **Root neck** — initially dark brown spots, which lignify and decay with time. During the ripening period, it causes the stems to break off. **Husks** — extensive, light brown spots surrounded by a brown border. On the surface of the spots, clusters of pycnidia are visible.	powdery mildew of brassica, cabbage black leaf spot, white rust
Grey mould	**Leaves** — recessed, irregular, blue-green spots covered with a greyish brown coating (mycelium and conidia of the pathogen). The leaves deform and die. **Stem** — recessed, irregular, grey-brown spots covered with grey coating (fungus and conidia of the pathogen). They can cause the stems to break and die. **Husks** — recessed, irregular, grey-brown spots covered with grey coating (fungus and conidia of the pathogen). The infection causes premature drying and cracking of the husks and falling of seeds.	dry rot of mustard, fungal rot, powdery mildew of brassica, white rust
Fungal rot	**Leaves** — zoned, grey-white spots. **Stem** — white-grey, sometimes concentrically zoned spots extending to the entire perimeter of the stem; inside, and often also on the surface of the stems, there is a dense, cotton-like, white mycelium and black, spherical spores of the fungus (sclerotia). **Husks** — husks whiten and on their surface and inside them mycelium develops and spherical, black sclerotia are formed.	grey mould
Seedling blight	**Seedling** — oval, brown necrosis including root neck and often root. Characteristic narrowings are formed, as a result of which the plant withers and dies.	damage by pests or use of the wrong herbicide

	Cotyledons — chlorotic necrosis and wilting. **Stem** — white mycelial coating of the pathogen (hyphal sheath).	

According to Kryczyński and Weber (2011); Jajor et al. (2017)

7.2.2. Agronomic methods of disease vectors control

The application of the agronomic method is based on the correct and timely execution of crop planning and management.

Agronomic activities play a significant role in combating or preventing diseases. They reduce diseases occurring especially in the early stages of mustard development.

In integrated pest management, the agronomic method is one of the most important methods of reducing the risk posed by pathogens. In the limiting conditions of alternative control methods, agronomic treatments are of particular importance. This is the case in crops in which other methods of protection, i.e. breeding, biological or chemical protection, are currently of little use.

The first step in enabling the plants to grow and develop properly, and thus be more disease-resistant, is to choose a suitable site. Correct crop succession is also an important element (Korbas et al. 2008). Crop rotation should take into account not only agronomic, but also phytosanitary requirements. Frequent cultivation of the same species or other species but of the same family, in this case winter rapeseed, spring rapeseed, turnip rape, etc., increases the risk from many harmful organisms, including the pathogens (Muśnicki 1999). This is due to the fact that these species are often infested by the same pathogens, and the more often they appear at a given site, the greater the amount of infectious material, e.g. spores of clubroot, fungal rot sclerotia, crop residues with fungal structures.

The crop must be located in such a way that it is not adjacent to crops of winter rapeseed, spring rapeseed or mustard. The closer the plantations of these species are located, the higher the risk of infestation of these crops by pathogens.

Seed of at least the qualified category should be used for sowing. It is important that the seeds are healthy, free from fungal spores on the surface and various contaminants, e.g. fungal rot sclerotia (Pusz et al. 2012). Greater resistance to infestation by disease vectors, e.g. seedling blight, cabbage black leaf spot, etc., is ensured by sowing to the right depth, the right amount of seeds, in a well-prepared soil. To some extent, also sowing in a wider row spacing, ensuring better ventilation of the crop, reduces the threat from the disease vectors (Toboła 2010).

As part of using the integrated protection of mustard from disease vectors, in accordance with Good Plant Protection Practice, the principles of phytosanitary hygiene should be applied consisting in cleaning of agricultural equipment and machinery used in harvesting crops, avoiding combining seeds from healthy and infected plantations. This is particularly important in limiting the infestation of plants by the clubroot pathogen (Korbas et al. 2008).

Table 5. The most important non-chemical methods of reducing mustard diseases

Disease	Reduction methods
White rust	crop rotation, healthy seeds, destruction of crop residues, spatial isolation from other brassica crops, optimal fertilisation, weed destruction
Cabbage black leaf spot	crop rotation, healthy seeds, destruction of crop residues, spatial isolation from other brassica crops, optimal fertilisation, destruction of weeds, sowing of varieties with increased resistance
Clubroot on mustard	crop rotation, liming before sowing, control of weeds of the brassica family in follow-on crops, water management in the soil; avoiding too early sowing; thorough cleaning of machines that were used in infected fields
Powdery mildew	crop rotation, destruction of infested plant residues, appropriate sowing rate and sowing date, optimal fertilisation
Downy mildew of crucifers	crop rotation, destruction of crop residues, optimal sowing date, appropriate depth and sowing rate, spatial isolation from other brassicas; sustainable fertilisation
Dry rot of mustard	crop rotation, destruction of crop residues, higher resistance varieties, pest control, spatial isolation from other brassicas, appropriate depth and sowing rate, optimal fertilisation
Grey mould	crop rotation, destruction of crop residues, spatial isolation of spring forms from winter forms, optimal fertilisation
Fungal rot	crop rotation (avoidance of brassica, legumes, Solanaceae, sunflower and other hosts), appropriate sowing standard of certified material; optimal fertilisation
Seedling blight	crop rotation, optimal date of sowing; the correct depth and standard of sowing; good soil structure, balanced fertilisation

7.2.3. Chemical methods of disease vectors control

The use of the chemical method in mustard cultivation is currently only possible during the growing season by spraying the plants. The purpose of this treatment is to protect plants from the most important diseases vectors found in mustard cultivation, if necessary. Seed of at least the qualified category which satisfies the production and quality requirements should be used.

The list of plant protection products authorised in Poland is published in the register of plant protection products. Information on the extent of pesticide use in particular crops is placed on the labels. A plant protection product search engine provides help in the selection of pesticide (https://www.gov.pl/web/rolnictwo/wyszukiwarka-srodkow-ochrony-roslin---zastosowanie). Current information on plant protection products use is available on the Ministry of Agriculture and Rural Development website at: https://www.gov.pl/web/rolnictwo/ochrona-roslin.

The list of plant protection products authorised for IP is available on the Online Pest Signalling Platform at: https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.html.

7.3. REDUCING LOSSES CAUSED BY PESTS

7.3.1. Most important pest species

The development of integrated rules for the protection of mustard against pests, taking into account environmental aspects, is particularly important due to the large number of species damaging this group of brassica plants. The extent of their harmfulness depends primarily on the weather conditions, the developmental stage and condition of the plant, as well as the method of cultivation. The vast majority of pests are those developing in both winter and spring rapeseed, including economically important species. In the case of mustard, the risk is lower, but it may occur each year when particular species can cause significant economic losses (Tables 6 and 7) (Jajor et al. 2017; Hołubowicz-Kliza et al. 2018).

Table 6. Importance of mustard pests in Poland

Pest	Importance	
	Current	Predicted
Rape seed weevil (*Ceutorhynchus napi*)	++	+++
Winter stem weevil (*Ceutorhynchus pallidactylus)*	++	+++
Cabbage gall weevil (*Ceutorhynchus obstrictus*)	++	++
Wireworms (Elateridae)	+	++
Leaf-eating caterpillars (Lepidoptera)	+	++
Turnip sawfly (*Athalia rosae*)	+++	+++
Whiteflies (Aleyrodidae)	+	++
Aphids (Aphididae)	++	++
Cabbage stem flea beetle (*Psylliodes chrysocephala*)	+++	+++
Flea beetles (*Phyllotreta* sp.)	++	+++
White grub (Scarabaeide)	+	++
Red spider mite (*Tetranychus urticae*)	+	++
Brassica pod midge (*Dasyneura napi*)	++	++
Cutworms (Agrotinae)	+	++
Common pollen weevil (*Meligethes aeneus*)	+++	+++
Gastropods (Molusca)	+	++
Cabbage maggots (*Delia brassicae*)	+	++

Diamondback moth (*Plutella xylostella*)	+	++
Thrips (Thysanoptera)	+	++

(+) pest of local importance, (++) important pest; (+++) very important pest

Table 7. Characteristics of damage caused by major mustard pests

Pests	Characteristics of damage
Rape seed weevil Winter stem weevil	The first symptoms are 'punctures' caused by beetles on a stem about 1 mm in size, initially mucous, then with a whitish edge; on the stem, during the growth of the main shoot, the lesions lengthen, form thin canals, thickenings and curvatures primarily in the lower part of the stem; in these places the stems crack, often break and constitute the entrance gateway for disease vectors; in the stem core, traces of larvae feeding can be identified.
Aphids	Adults and larval stages of aphids are harmful. Aphids inhabit younger, apical fragments of plants. As a result of feeding aphids, the growth of plants is inhibited. Inhabited plant fragments may become deformed, wither, and dry out. Spores or other factors causing secondary fungal and bacterial infections may enter the feeding sites of aphids through damaged tissues.
Thrips	In the case of a vast infestation with the pest, small, necrotic spots are visible on the damaged leaves (white on flowers, silver on young pods); eventually these organs wither and fall, and the pods become stunted. The harm caused by thrips is the greater, the younger the plants that are attacked.
Cabbage gall weevil	Damaged husks remain closed, however, they turn prematurely yellow, are slightly deformed and have 1 small hole; inside a husk 1 larva can be found feeding on the seeds.
Cabbage fly	Brown discolouration and rotting areas occur on the root neck and roots; side roots are partially dead and it is difficult to see them present when the plants are removed from the ground; there are canals in the outer layer of the root and inside the root neck with a dead tissue where the larvae of the cabbage fly feed.
Grubs Cutworms	Larvae damage the underground parts of plants. They can eat imbibating seeds, seedling roots, or gnaw the stems of young plants at the base. Mass foraging of the larvae is manifested by patchy losses in the crop (the so-called bald spots), mainly from the edges of plantations.
Caterpillars that damage the leaves	Butterfly caterpillars feed on leaves and, in cases of mass occurrence, can lead to partial defoliation of plants.
Turnip sawfly	On the underleaf, losses of tissue scraped off by young larval stages and small holes in the leaf can be observed; later, older larval stages may devour the entire foliage of the plant, where whole leaves are eaten, with only the main nerves, inflorescences and husks remaining.
Whiteflies	Adult individuals and larvae feed on the underleaf sucking out the sap; the leaves may deform and gradually dry out.
Flea beetles	The cotyledons and leaves show typical foraging symptoms (bitten out holes and skeletonisation of the leaves); a very large population leads to sieve-like damage to the leaves; more significant is the mining feeding in the leaf tails,

	leaf nerves and its core; brown meal or ivory larvae can be found in the canals.
Red spider mites	Pest particularly active in dry and hot years. Symptoms of mass appearance of spider mites include weakening of plant development, drying and wilting of leaves, necrosis. So far, the importance of the pest in mustard is small.
Brassica pod midge	Damaged husks prematurely turn yellow, swell, often become deformed near the apex, shrink and prematurely crack; inside the husks there are numerous larvae (from 5 to 100) destroying seeds.
Common pollen beetle	Typical symptoms are caused by beetles biting out flower buds, a part becoming completely hollowed out; damaged buds turn yellow, wither and then fall off, only peduncle remains; the result is irregular inflorescences, or irregularly spread husks.
Gastropods	After emergence, the seedlings are either entirely eaten or nibbled until completely cut off by slugs, just above the soil surface.
Diamondback moth	On the leaves, numerous, small, round or irregular windows can be found, formed after the caterpillars scrapes off the lower epidermis and ground tissue; the upper epidermis cracks as the leaf grows and holes are formed.

7.3.2. Pest monitoring methods

Monitoring for the presence of pests in a plantation is a very important part of integrated plant protection. Continuous observation facilitates the assessment of the current situation in the field and, if necessary, allows for a quick response. Therefore, it is necessary to systematically monitor the occurrence of pests from the time of emergence to maturation, at least once a week, using appropriate methods. The basic element underpinning a properly set date for pest control is the monitoring of pest flights and number. Monitoring is carried out primarily on the basis of visual inspection or, in the case of soil pests, soil sieving. Other methods are also useful, such as sweep-netting or sticky boards. The basic method of plantation inspection is visual inspection (tour). Depending on the shape of the field, it should include the edge of the plantation and two diagonals. Depending on the pest species, the average number of pests per 1 m^2 or on 100 randomly selected plants should be checked. Such observations should be carried out in several places on the plantation. A useful method is sweep-netting. This is an easy and quick way to make an initial assessment of the species composition and number of insects on a plantation. This method of monitoring, with the correct application, provides preliminary information not only about pests, but also about other insects, including useful ones located on the plantation in a relatively short time. However, it should be remembered that this method is not precise and in the event of a detected threat, more detailed inspection of the plantation should be carried out. For the purpose of initial inspection, 25 strokes should be carried out with a sweep net from the edge of the plantation, moving inwards. Sweep-netting should always be carried out in the place most vulnerable to pest infestation, for example from last year's location of the crop concerned. Observations on the occurrence of soil pests consist of sieving the soil sampled at several sites from holes measuring 25 × 25 cm and 30 cm deep. The essence of proper pest risk assessment is to know the basics of the morphology and biology of a given pest species,

e.g. the timeline of its potential occurrence on the crop. Monitoring should be carried out both in order to determine the time of infestation and number of harmful insects on the plantation, as well as after the procedure to check the effectiveness of the control. In case of unsatisfactory effectiveness, the occurrence of resistance or prolonged infestations of harmful insects, such treatment gives the possibility of a quick reaction and, if possible, a repeat treatment. Due to many factors determining the occurrence of pests, monitoring should be carried out on each plantation. Proper inspection requires knowledge of pest morphology and biology. Regardless of the monitoring method used, the results of inspections should be recorded (Mrówczyński et al. 2017, Tratwal et al. 2018).

Constant monitoring is necessary to determine the optimal treatment timing due to the continuous impact of many environmental factors. Only direct observations make it possible to assess the actual threat from pests. Threats can vary depending on climatic conditions, terrain, plant growth stage, natural enemies or even fertilisation level.

Integrated plant protection programmes require considerable knowledge and experience from the farmer, ranging from pest identification to elements of development and habitation to ways of pest reduction and elimination. Information on pest biology, data from previous years on the occurrence of a pest in a given area combined with knowledge of measures to reduce losses can help in deciding on a treatment. The benefits of knowledge of modern methods of plant protection are not only economic. The lack of chemical pest control also translates into a healthier environment.

One of the tools facilitating the implementation of the principles of integrated plant production is systems supporting the adoption of decisions in plant protection. These systems are helpful in determining the optimal deadlines for performing plant protection treatments (in correlation with the plant growth phase, pest biology and weather conditions), and thus make it possible to achieve high efficiency of these treatments while limiting the use of chemical plant protection products to a necessary minimum.

The Online Pest Signalling Platform managed by the Institute of Plant Protection — State Research Institute and partner institutions contains, among other things, the results of monitoring of individual stages of pest growth in selected locations for the needs of short-term forecasting. If the threshold of economic harmfulness is exceeded in individual cases, the system indicates the need to perform treatments. In addition, the system offers instructions that facilitate proper control of plantations and taking decisions about the optimal treatment dates. For each pest species, basic information is provided on its morphology, biology and methods of field monitoring. There are currently no specific economic damage thresholds for mustard pests. Treatments should be carried out in accordance with the signalling after the appearance of pests. The rules and dates for their observation are set out in Table 8.

Table 8. Time limits and rules for the monitoring of mustard pests

Pest	Principle and period of observation
Rape seed weevil	the presence of beetles on plants: the beginning of the development of lateral shoots into the phase when the first flower petals are visible, but the flower buds are still closed (BBCH 20–59).
Winter stem weevil	the presence of beetles on plants: the beginning of the development of lateral shoots into the phase when the first flower petals are visible, but the flower buds are still closed (BBCH 20–59).
Common pollen beetle	presence of beetles on plants and damaged flower buds: visible 9 internodes to the phase when the first flower petals are visible, but the buds are still closed (BBCH 39–59).
Cabbage gall weevil	the presence of beetles on plants: the first flower petals are visible, but the buds are still closed to the phase when 10 % of the husks have reached their final size (BBCH 59–71).
Brassica pod midge	presence of midges on plants: the first flower petals are visible, but the buds are still closed to the phase when 10 % of the husks have reached their final size (BBCH 59–71).
Aphids	presence of aphid colonies on all vegetative organs leaf development (BBCH 10–19) and from the development of the first lateral shoots to the end of fruit development (BBCH 20–79).
Turnip sawfly	Presence of hymenoptera and larvae and damage caused by them: leaf development (BBCH 10–19) and from the development of the first lateral shoots to the end of fruit development (BBCH 20–79).
Flea beetles	the presence of beetles on plants or damage caused by them: leaf development (BBCH 10–19) and from the development of the first lateral shoots to the end of fruit development (BBCH 20–79).
Leaf-eating caterpillars	inspection of crops for the presence of caterpillars, cocoons and faeces and leaf damage: shoot development to pod maturation (BBCH 21–75)
Wireworms	plant stock losses: first fully developed leaf to full maturity (BBCH 11–89).
Whiteflies	presence of adult insects and larvae on leaves: from the first fully developed leaf to full maturity (BBCH 11–89).
Thrips	presence of adult insects and larvae on all vegetative organs: first fully developed leaf to full maturity (BBCH 11–89).
Red spider mites	the presence of arachnids on plants: first fully developed leaf to full maturity (BBCH 11–89).

7.3.3. Agronomic methods of pest control

Preventive actions based primarily on agrotechnology are one of the basic assumptions behind integrated mustard protection against pests. Appropriate use of agricultural technology and the replenishment of any mineral nutrients shall improve the condition of plants in particular in the early growth stages, when they are particularly vulnerable to attack from particular pest species. Properly conducted protection is intended to encompass a wide range of agronomic methods. The increasingly common use of simplified cultivation methods in connection with climate change creates favourable conditions for the development of pests. Proper adherence to basic agronomic recommendations is a key element of the programme of mustard protection against pests (Table 9).

Table 9. Non-chemical methods of reducing the abundance of mustard pests

Pest	Protection methods and measures
Pieris butterflies	cultivation and plant care treatments, spatial isolation from other brassicas
Cabbage gall weevil	cultivation and plant care treatments, spatial isolation from other brassicas, sowing of late-flowering varieties
Turnip sawfly	spatial isolation from other brassicas, early seed sowing, increasing the seed sowing standard
Aphids	spatial isolation from other brassicas, early seed sowing
Flea beetles	spatial isolation from other brassicas, early seed sowing, increasing the seed sowing standard
Grubs	cultivation and plant care treatments, early seed sowing, increasing the seed sowing standard
Brassica pod midge	cultivation and plant care treatments, spatial isolation from other brassicas, sowing of late-flowering varieties
Cutworms	cultivation and plant care treatments, spatial isolation from other brassicas, early seed sowing, increasing the seed sowing standard
Common pollen beetle	cultivation and plant care treatments, spatial isolation from other brassicas, sowing of early flowering varieties
Snails	cultivation and plant care treatments, spatial isolation from other brassicas, early seed sowing, increasing the seed sowing standard
Cabbage fly	spatial isolation from other brassicas, early seed sowing, increasing the seed sowing standard
Diamondback moth	spatial isolation from other brassicas
Thrips	spatial isolation from other brassicas

In the case of mustard, as in other brassica species, the use of proper crop rotation is very important. Many pests overwinter in the top layer of soil or leftover plant residues. In the case of monocultures, pests after wintering have facilitated access to the food base. For the same reason, it is recommended to use spatial isolation from other brassica plants. Spatial isolation also helps make certain pests fly over longer distances.

Preparation of the place for cultivation, possible addition of minerals and further balanced fertilisation improves the condition of the plants. This is particularly important in the early stages of plant growth when they are extremely sensitive to attack by individual pest species. Appropriate measures to reduce the potential damage caused by individual pest species can also be taken at the seed sowing stage. Faster initial vegetation of plants makes it possible to get ahead of the period of greatest danger from all pests, especially those that are dangerous for emergence. In addition, faster growth helps choke weeds that can be a food base for some pests. The plant density is also important. Too dense sowing makes it easier for pests to spread, while sowing too sparsely promotes weed infestation. In addition to competition for water, light and nutrients, weeds are also the food base for some pests, e.g. aphids. The date of harvest is also very important; harvesting too late creates a risk of greater losses, especially qualitative, by insects that can damage the husks.

After harvesting, it is important to perform post-harvest cultivation treatments, aimed at precise fragmentation of crop residues (places of wintering and development of certain pests), controlling weed seeds, including the perennial ones. Post-harvest tillage should be completed by deep autumn ploughing, which serves a phytosanitary role. A thick layer of soil covers the wintering stages of pests, weed seeds and fungal spores. It also brings to the surface pests that are found deeper, exposing them to adverse weather conditions. At the same time, soil pests are mechanically destroyed (Tratwal et al. 2018).

7.3.4. Chemical methods of pest control

Plant protection products should be used in accordance with the current list of plant protection products recommended for mustard in integrated production (IP). Use instructions on the label should be read before application. The messages provided in the Online Pest Warning System (www.agrofagi.com.pl) may be helpful. The list of plant protection products authorised in Poland is published in the register of plant protection products. Information on the extent of pesticide use in particular crops is placed on the labels. The plant protection product search engine is a helpful tool in the selection of pesticides (https://www.gov.pl/web/rolnictwo/wyszukiwarka-srodkow-ochrony-roslin---zastosowanie). Current information on plant protection products use is available on the Ministry of Agriculture and Rural Development website at: https://www.gov.pl/web/rolnictwo/ochrona-roslin.

The list of plant protection products authorised for IP is available in the Pest Signalling Platform at: https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.html.

8. BIOLOGICAL METHODS AND PROTECTION OF BENEFICIAL ENTOMOFAUNA IN INTEGRATED PRODUCTION OF MUSTARD

Biological methods in integrated plant production

Biological methods consist in the use of such biological factors as viruses, bacteria, fungi, nematodes and entomophages (parasitic and predatory insects) to reduce harmful organisms' (pests, plant disease vectors and weeds) populations in fields and in covered plantations. Biological methods in most cases work slower than traditional chemical protection. This is influenced by a number of factors, including environmental conditions, but also the biology itself and the mechanism of action of a biological agent on the controlled pest species. Biological methods may be interventionist in nature, but in most cases they act as a preventative measure, reducing the development of pest species (Fiedler 2007).

There are three main methods of biological pest control:
- **classic method** (introduction), in which natural enemies are introduced into new areas from other regions or continents;
- **conservation method** that consists of the protection of beneficial organisms by making changes to the environment that are beneficial to them and by the use of selective plant protection products;
- **augmentative method**, in which natural enemies of a particular pest are introduced on a regular basis into crops where the pest is not present or is present only in small numbers.

In biological protection, it is important to plan treatments correctly depending on what is happening in a particular area. Monitoring the pest outbreak, including historical knowledge of the phytosanitary status of the crop from previous seasons, allows for biological protection of mustard to be planned accordingly.

Reducing the population of pests in mustard with the use of bioinsecticides

Mustard is infested by pests which are present in the cultivation of rapeseed. The greatest damage is caused by the cabbage gall weevil, turnip sawfly, common pollen beetle, aphids, and, during the emergence, beetle fleas. Cutworms, white grubs and wireworms are also a problem. Bioinsecticides containing the insecticidal bacterium *Bacillus thuringiensis* are used to control leaf-damaging caterpillars (e.g. cutoworms). To select a registered bioinsecticide, use the List of Plant Protection Products for Integrated Production (https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-

produkcji) or the Plant Protection Products search engine at the Ministry of Agriculture and Rural Development website at: (https://www.gov.pl/web/rolnictwo/wyszukiwarka-srodkow-ochrony-roslin---zastosowanie). The death of an insect occurs after the ingestion of spores and toxic bacterial crystals that cause damage to the epithelial cells of the intestine. The digestive tract is paralysed and the insect stops feeding. The most sensitive are the younger larval stages of insects.

Bioinsecticides containing the insecticidal fungus *Beauveria bassiana* may be used to control whiteflies, red spider mite, thrips and wireworms if they are registered and recommended for integrated plant production. The infective stage of the fungus is the spores, which need to reach the surface of the pest's body. Then, under the right conditions (temperature >20 °C and high humidity), they germinate and penetrate its interior. The insect dies from paralysis caused by the overgrowth of its body by the developing fungal hyphae. All stages of pest development are vulnerable. One of the symptoms of fungal infestation is mummification; the body of the pest is hard and on its surface a mycelium of different colours is formed along with spores.

When using micro-organisms to control mustard pests, it should be remembered that:

- they are sensitive to high temperatures and strong sunlight;
- the bacteria are best used when the first caterpillars/larvae of the pest appear, as the younger stages of the pest are more sensitive to insecticidal bacteria;
- insecticidal fungi in their first stage of action require temperatures of around 25 ^{0}C and high humidity to germinate and enter the insect;
- the pest's caterpillars die 24–72 hours after consuming the fungal spores. During this time, they can feed and look healthy.
- Micro-organisms are applied using self-propelled or tractor-mounted sprayers. Such treatments should preferably be carried out in the evening or early morning.
- Chemical fungicides must not be used after the use of biological agents containing micro-organisms;
- they are living organisms and have a short shelf life at room temperature, but can be stored in the refrigerator for up to 6 months.

Reducing of mustard disease pathogens with the use of biofungicides

For the protection of brown mustard, biofungicides containing *Trichoderma asperellum* antagonistic fungus strain may be used to reduce seedling blight, root rot caused by *Fusarium* spp., *Pythium* spp. (brown mustard), if such biopreparations are registered.

The antagonistic fungus *T. asperellum* inhabits the root zone of plants and substrates, thus competing with other pathogens for nutrients and living space.

Rules for the use of biological plant protection products

Biological plant protection products must be used in accordance with the product label. The content of the label is the basis for achieving the effectiveness of the product. Its instructions must be strictly adhered to.

The quality of the biopreparation is the responsibility of the manufacturer or the distributor, but its proper storage after purchase is the responsibility of the farmer.

It should be stressed that biological agents contain living organisms (e.g. fungal spores, bacteria) that are very sensitive to environmental conditions, have different mechanisms of action and do not eliminate pests like the chemical plant protection products used, but significantly reduce their populations, usually during a longer period of action.

General rules for the use of preparations containing parasitic and antagonistic fungi

The infectious form of the insecticidal fungus, which is the active substance of the bioinsecticide, consists of spores of the fungus, which do not have to be ingested by the pest; it is sufficient for them to reach the surface of the host's body. They sprout and penetrate its interior. The insect dies from paralysis caused by the overgrowth of its body by the developing fungal hyphae. All stages of pest development are vulnerable. The time from infection to the death of the pest is from 3 to 7 days.

Insecticidal fungi, such as *Beauveria bassiana*, are sensitive to low and very high temperatures. The optimal temperature for spore germination is 25 ^{0}C. High humidity is required for the penetration of spores into the body of the pest. Micro-organisms are applied using self-propelled or tractor-mounted sprayers. The use of an insecticidal fungus in the form of a registered biopreparation means that the biological agent introduced into the environment can also act on other pests not listed on the label of the product for a long period of time. Fungus *B. bassiana* is a known biological agent commonly found in soil and may, for example, reduce the different stages of development of pests wintering in soil.

Symptoms of infestation by insecticidal fungi: the body of an infested insect often changes colour. One of the typical symptoms is mummification; the body is hard, and on its surface in humid conditions, a mycelium of different colours is formed, depending on the species of the fungus. Biological preparation containing parasitic fungi should be stored under cool conditions at a temperature of 2 °C to 6 °C. Insecticidal fungi may be used together because no interaction between them is observed.

General rules for the use of preparations containing bacteria

The death of an insect occurs after spores and toxic bacteria crystals are ingested, resulting from damage to the epithelial cells of its intestine, caused by endotoxin activity. The digestive tract is paralysed and the insect stops feeding. The most sensitive are the younger larval stages of insects. The body of the infested insect darkens and becomes almost black due to necrotic changes.

It is important to remember that:

- In the environment, biological factors, i.e. elements of the living environment, directly or indirectly affect the life of organisms. An example is the antagonistic action of bacteria of the genus *Bacillus* and *Pseudomonas* on the insecticidal fungus *B. bassiana*. These species should not be combined with each other.

- Bacteria should be applied to the younger larval stages of pests, because they are the most sensitive to them.

- When preparing a suspension of a preparation containing the bacterium *Pseudomonas* sp., it should be remembered that the water used for the preparation of the suspension should be at a temperature of 15 C–25 °C.

- When treated with *Pseudomonas* sp., the spray tank must be filled with a suspension of the medium and water in an ultra-low volume application system (ULV).

Conservation biological protection

In plant protection, biopreparations alone are not capable of reduce pest populations in the same way as chemical plant protection products used. Biological protection is not only about the use of registered microbiological biopreparations. It is supported by conservation biological protection, which consists of human modification of the agricultural landscape to create suitable conditions for the development of beneficial organisms in the environment. Under favourable conditions, macro-organisms acting in the environment can reduce pest populations in mustard cultivation and thus support the action of biological agents. Rapeseed pests, which are also mustard pests, host over 88 parasitoid species, e.g. the common pollen beetle is attacked by 9 parasitoid species, and turnip gall weevils by as many as 42 parasitoid species. The Carabidae reduce the pupae by of common pollen beetle up to 50 %. Ladybugs, lacewings and hoverflies feed on aphids. Insecticidal fungi in the soil environment can reduce the overwintering stages of pests, such as the fungus *Metarhizium* spp. Insecticidal fungi often cause epizootics (mass death) in aphid colonies. An important role is played by insecticidal nematodes, which destroy the common pollen beetle and the cabbage gall weevil in the soil. The action of these biological factors in the environment can be supported by keeping baulks empty, planting trees in the field, sowing melliferous plants (buckwheat, phacelia, borage and others), sowing flower strips and applying appropriate agronomic methods. It should be noted that macro-organisms are not subject to registration in Poland. Insecticides containing nematodes can be purchased, but there is no strategy for their introduction in mustard cultivation.

In reducing mustard pests, it is also important to protect their natural enemies, which can reduce the populations of various pests in the environment. Beneficial organisms in the environment include: predatory ground beetles, rove beetles and ladybirds, parasitic flies (e.g. Tachinidae) and sawflies (e.g. aphids and Ichneumonidae), predatory flies (e.g. hoverflies and midges), predatory hemiptera and lacewings, and many others that contribute to natural environmental resistance.

In the soil environment, various species of insecticidal fungi can act in favourable conditions to reduce the number of grubs, for example. These are: *Beauveria bassiana*, *B. brongniartii*, *Cordyceps fumosorosea*, *C. farinosa* and *Metarhizium anisopliae*. Aphids on leaves can be infected by insecticidal fungi of the *Entomophthoraceae* family. Often, at high temperatures and humidity, they cause epizootics, i.e. mass death of aphid colonies in mustard crops. That is why it is so important to carry out treatments that have a beneficial effect on the growth of biodiversity in the natural environment of arable fields (Sosnowsa and Fiedler 2013).

Activities that support the effectiveness of biological agents in the environment:
- leaving dead furrows, thickets, shrubs and mid-field refuges that support the development of beneficial insects and micro-organisms that live there;
- forest surroundings are a refuge for beneficial insects and micro-organisms (e.g. insecticidal fungi);
- sowing melliferous plants and creating flowering strips among crops;
- use of organic fertilisers;
- crop rotation;
- cultivation technologies, e.g. zero-tillage cultivation (higher soil moisture contributes to the effectiveness of insecticides);
- the use of selective chemical plant protection products.
- according to the List of Obligatory Measures, suitable conditions must be created for the presence of birds of prey, i.e. resting poles must be provided at a rate of at least 1 per 5 ha, or several in the case of larger plantations.

Plant protection products, including biological agents, should be used in crops for which they are recommended and the information contained in the labelling of the product must be observed. The basis for their application is the monitoring of harmful species.

In the environment, not only beneficial insects and micro-organisms play a role in reducing harmful pest populations. Other animals do too, such as amphibians, birds or mammals (Wiech 1997). The common toad feeds on a variety of foods, predominantly gastropods and insects, often of the harmful species. One of the insectivorous mammals is the mole. It is a beneficial animal that feeds on white grubs and other insects found in the soil. The largest representative of insectivorous mammals is the hedgehog, which hunts at night, and its food consists in insects, gastropods and other animals. Birds play a useful role in the environment.

Detailed information on registered plant protection products for the protection of mustard can be found in the search engine of plant protection products at the website of the Ministry of Agriculture and Rural Development:
https://www.gov.pl/web/rolnictwo/wyszukiwarka-srodkow-ochrony-roslin---zastosowanie.

The list of plant protection products for integrated production is available on the website https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.

Protection of bees and other pollinators

Legal protection of these organisms during chemical treatments is also an important element of modern plant protection. Integrated plant protection includes 'protection of beneficial organisms and creating favourable conditions for their occurrence, in particular for pollinators and natural enemies of harmful organisms' (Hałubowicz-Kliza et al. 2018).

Bearing in mind the obligation to carry out crop protection in accordance with the principles of integrated pest management, chemical plant protection treatments should take into account the selection of plant protection products in such a way as to minimise their negative impact on non-target organisms, in particular pollinators and natural enemies of harmful organisms.

A more efficient use of beneficial species can be achieved through a number of actions, including:

- The rational use of chemical plant protection products and basing decisions on the real risk to the mustard crop posed by pests, assessed on an ongoing basis. One should consider abandoning treatments if pests do not occur in large numbers and are accompanied by the occurrence of beneficial species. In this group of activities, the limitation of the treatment area to treatments on the edges and in patches should be considered if the pest does not occur on the whole plantation. The use of tested mixtures of plant protection products and liquid fertilisers, which reduce the number of entries into the field and mechanical damage to plants, should be recommended.
- Protection of beneficial species by avoiding the use of insecticides with a broad spectrum of action and replacing them with selective agents;
- Choosing the treatment time to prevent high mortality among beneficial insects;
- Based on the results of analyses, dose reduction and adjuvant addition;
- Constant awareness that protecting natural enemies of pests also protects other beneficial species present in the field;
- Leaving dead furrows and mid-field shelters as a habitat for many species of beneficial insects.
- reading the content of the label accompanying each plant protection product carefully and observing the information contained therein.

Other insects are also very efficient pollinators. In order to ensure the development of pollinators living in the wild in agrocenoses, and thus increase pollination efficiency, it is necessary to place mason bee houses or bumblebee mounds (scattered bags of peat) or other facilities for pollinators within the crop—at least 1 per 5 hectares.

9. PROPER SELECTION OF PLANT PROTECTION TECHNIQUES

Storage of plant protection products

Plant protection products should be stored:

a) in their original packaging, tightly sealed and clearly labelled and in such a way that they do not come into contact with food, drink or feed;

b) in a manner ensuring that they:

- are not consumed or intended for animal feeding,
- are inaccessible to children,
- there is no risk of:
  - contamination of surface and groundwater within the meaning of the water law,
  - soil contamination due to leakage or seepage of plant protection products into the soil profile,
  - penetration into sewage systems, excluding separate drain-free sewage systems equipped with a leak-proof sewage tank or equipment for their neutralisation.

The labels of plant protection products approved by the Minister for Agriculture and Rural Development contain information on the principles of safe storage.

Plant protection products in accordance with the principles of good practice should be stored in separate rooms (except residential and livestock buildings). These rooms should be clearly marked (e.g.: 'plant protection products') and protected against unauthorised access, i.e. locked.

If poisoning is suspected in connection with contact with a plant protection product, medical advice should be sought immediately and the doctor informed of the method of exposure to the specific chemical in question.

Requirements for professional users

Persons or sprayer operators handling plant protection products must be suitably qualified, attested to by a certificate of completion of training in the use of plant protection products or advisory on plant protection products and integrated plant production or another document attesting to their rights to carry out plant protection treatments.

The sprayer operator must be equipped with appropriate protective clothing, as prescribed by the label and the safety data sheet of the plant protection product. The basic equipment of protective clothing includes: a suit, suitable shoes, rubber gloves resistant to plant protection products, glasses and mask to protect the eyes, respiratory system and covering the mouth. Proper work organisation and available technical measures should be used at each stage of the treatment of plant protection products, in accordance with the principles of Good Plant Protection Practice.

Apparatus and equipment for protective treatments

The sprayer or other equipment used for crop protection must be technically efficient, ensure reliable operation and guarantee the safe use of plant protection products, liquid fertilisers or other agrochemicals. The sprayer must have undergone a technical inspection (with up-to-date certification) and be properly calibrated. The technical efficiency of the equipment is confirmed by the protocol of the test carried out and by the control mark issued by the units authorised to do so (sprayer inspection stations). Testing of new equipment must be carried out no later than five years after its acquisition and subsequent tests must be carried out at intervals of no more than three years.

Equipment used for plant protection treatments must be safe for humans and the environment. In addition, it should guarantee the full effectiveness of protective treatments by ensuring proper action to allow accurate dosing and even distribution of plant protection products on the treated area of the field.

Before performing the procedure, it is necessary to check the technical condition of the sprayer, in particular the condition of: filters, pumps, lubrication and lubrication points, nozzles, field beam, measuring and control devices, liquid system and agitator. It is also advisable to carry out a preventive rinse of the sprayer to remove mechanical debris and any residues of previous treatments from the system.

Calibration (adjustment) of the sprayer

Periodic adjustment of the sprayer makes it possible to choose the optimal parameters of the treatment. In accordance with good plant protection practice in the adjustment (calibration) process of the sprayer, the type and dimension of the sprayers and the working pressure should be determined, which ensure the application of the assumed dose of liquid per hectare for the specified operating speed of the sprayer.

The adjustment of the sprayer's operating parameters should be performed when changing the type of chemical agent (especially from herbicide to fungicide or insecticide), the dose of the spray liquid, as well as the setting of operating parameters (working pressure, field beam height). The adjustment of the sprayer is carried out each time when replacing important equipment and components of the sprayer (sprayers, pressure gauge, control device, repair of essential elements of the liquid system), as well as when changing the tractor or tyres in the drive wheels. The discharge of the liquid from the nozzles at the specified operating pressure should be checked regularly. When adjusting the sprayer, attention should be paid to the flow capacity of the nozzles and the uniformity (type and size) of the nozzles mounted on the field beam.

An example procedure for calibration of the sprayer is contained in the Code of Good Practice for Plant Protection or other thematic studies in this area.

Choice of plant protection product and dosage

In line with the requirements of integrated pest management, selective measures with low risk to pollinators and beneficial organisms should be chosen.

Treatments with plant protection products should be planned in a way that ensures acceptable efficacy with the minimum quantity of plant protection product necessary, taking into account local conditions.

The dose of the plant protection product should be selected according to the producer's recommendation on the basis of the label, also taking into account the developmental stage of plants, their condition and climatic and soil conditions: wind, temperature and humidity of soil and air, type of soil as well as the content of organic matter in the soil.

The decision to use a plant protection product at a dose lower than that recommended on the label must be taken with great care, based on knowledge, experience, observations and professional advice. The use of reduced doses may lead to the development of resistance to active substances of plant protection products in target organisms.

When using plant protection products, also in split doses, it is necessary to comply with the requirements specified on the product label, i.e.:

- **time intervals between various treatments;**
- **maximum number of uses per season;**
- **the maximum dose of the plant protection product.**

Selection of spray liquid volume

In integrated crop protection systems, the volume of spray (l/ha) should be selected based on available catalogues, training materials and handbooks or other thematic studies. Factors such as the type of crop being sprayed, the development stage of the crop, the density of the crop, the possibility of using different spraying techniques (type of treatment apparatus, type and kind of spray equipment), as well as the recommendations contained on the label of the specific plant protection product, should be taken into account in the selection of spray volume.

Surface agents require very good coverage of sprayed plants and generally require the use of more spray fluid than systemic agents. In foliar feeding treatments and when combining the use of several chemicals, it is recommended to use increased volumes of spray liquid. With suitable treatment equipment (e.g. sprayers with auxiliary air stream [(AAS]), the dose can be possibly reduced to 50–100 l/ha which should guarantee sufficient coverage of the treated plants.

Selection of sprayers

Spray nozzles have a direct impact on the quality of spraying and thus on the safety and effectiveness of plant protection products. Catalogues and general recommendations concerning their use for the protection of agricultural crops are useful in the selection of suitable sprays for individual plant protection treatments. The selection of the atomiser for specific protective treatments should be preceded by getting to know its technical

characteristics, and above all information about the type, size of the spray slot, and intensity of the liquid discharge.

Preparation of spray liquid

The intended volume of the liquid should be prepared immediately before the procedure to avoid undesirable physicochemical reactions. The sprayer agitator must be switched on at all times to protect the mixture from precipitation at the bottom of the tank. Before pouring the product into the tank, it is necessary to read the indications on the label as to the method of preparation of the spray liquid and the possibility of mixing the product with other preparations, adjuvants or fertilisers.

The measurement of plant protection products and preparation of the spray liquid should be carried out in a way that reduces the risk of contamination of surface water, groundwater and soil and at a distance of no less than 20 m from wells, water intakes, reservoirs and watercourses.

Sprayer filling:

- the sprayer must be filled on an impermeable and hardened surface (e.g. concrete slab), in a place where it is possible to prevent the spreading of spilled or leaked plant protection products;
- the measured quantity of crop protection product should be poured into the partially filled tank with the agitator switched on or in accordance with the instructions for use of the sprayer;
- empty plant protection product packaging must be rinsed three times, the contents poured into the spray tank, and the packaging preferably returned to the dealer;
- if possible, it is best to fill the sprayer on a special stand with a biologically active substrate;
- when filling the sprayer on permeable ground, a thick plastic foil for collecting spilled or spread preparations should be laid down where the plant protection products are measured and introduced into the sprayer tank,
- spilled or scattered plant protection product and contaminated material must be safely managed using absorbent material (e.g. sawdust);
- contaminated absorbent material must be collected and submitted to a bioremediation site for plant protection products or placed in a sealed, labelled container;
- the container containing the contaminated material should be stored in plant protection product storage until safely disposed of.

Combined use of agrochemicals

In treatments with the use of several agrochemicals, the order of adding ingredients during the preparation of the spray liquid should be observed. A weighed portion of fertiliser (e.g. urea, magnesium sulphate) is poured into the sprayer tank half filled with water with the stirrer on. Further components are added to this solution. It is recommended that they

be pre-diluted before pouring into the sprayer tank. Start with an adjuvant that improves compatibility of the components of the mixture, if used. Then plant protection products are added (in the correct order, according to the formulation), followed by water to the desired volume of the sprayer tank.

In multiple-component mixtures with the use of two or more plant protection products, the order of their addition to the liquid should be followed according to the physical characteristics of the formulations. First, add preparations that form a suspension in water, then add agents that form emulsions, and finally, solutions. After adding all the components, fill the tank up with water to the required volume.

Do not use water at a low temperature (taken directly from a deep well) for the treatment. Very hard and contaminated water should not be used. Protective treatments may begin when the spray liquid is properly prepared.

Treatment conditions

Plant protection products should be used in such a way that they do not pose a risk to human health, animal health and the environment, including preventing the spread of plant protection products to areas and facilities not intended for treatment

Treatments with plant protection products should be carried out in light wind and rain-free weather and moderate temperature and sunshine. Spraying during adverse weather (stronger wind, high temperature and low air humidity) can cause damage to other plants as a result of the spray liquid drifting to areas not to be covered by the treatment, and may cause unintended poisoning of many beneficial species of entomofauna.

Table 10. presents the recommendations for optimal and limiting weather conditions during spraying operations. The recommended air temperatures during treatments are conditioned by the type and mechanism of action of the plant protection product applied and such data are included in the label texts. For most preparations, optimal effectiveness is achieved at a temperature of 12–20 °C.

Plant protection products can be applied in the open if the wind speed does not exceed 4 m/s. A slight wind, with a speed of 1 to 2 m/s, is also beneficial due to turbulence and better movement of the sprayed liquid among the sprayed plants. In weather conditions close to the upper (temperature and wind speed) or lower (air humidity) limit values, drift-limiting spray nozzles (e.g. low drift or ejector nozzles) and lower recommended operating pressures should be used for spraying operations.

Table 10. Limit and optimal meteorological conditions for plant protection treatments

Parameter	Limit values (extreme)	Optimal values (most favourable)
Temperatures	1–25 °C during treatment	12–20 °C during the treatment
	up to 25 °C the day after the treatment	20°C the day after treatment
	not less than 1°C the next night	not less than 1°C the next night

Air humidity	40–95 %	75–95 %
Rainfall	less than 0.1 mm during treatment	no rainfall
	less than 2.0 mm within 3–6 hours of the treatment	
Wind speed	0.0-4.0 m/s	0.5-1.5 m/s

Plant protection products can be used in open areas by means of tractor sprayers and self-propelled field or fruit sprayers, if the place of application of these products is located:

- at least 20 m from the apiaries,
- at least 3 m from the edge of the roadway with the exception of public roads classified in the category of municipal and district roads,

and

- in the case of tractor and self-propelled orchard sprayers, at least 3 m from reservoirs and watercourses and land not used for agriculture, other than for treatment with plant protection products,
- in the case of tractor and self-propelled field sprayers at a distance of at least 1 m from reservoirs and watercourses and land not used for agriculture, other than those treated with plant protection products.

It is important to bear in mind the obligation to comply with the labelling of plant protection products in the first place. On many labels, distances (buffer zones) from specific sites and facilities for the use of plant protection products are greater than those indicated above.

The spraying procedure is performed at a constant movement speed and working pressure, set during sprayer adjustment. Successive runs through the field should be made very precisely so as to avoid the formation of strips which are not sprayed and so that no overlapping of the sprayed liquid occurs in the areas already sprayed (Kierzek et al. 2012).

Post-treatment procedure

At the end of each treatment cycle, removal of the spray liquid from the sprayer should be carried out by spraying the spray liquid in the field or plantation where the treatment was carried out or on the producer's own unused agricultural area, away from drinking water intakes and drains. The sprayer must be washed thoroughly in the place intended for this purpose.

The remaining liquid must not be poured into the soil or into the sewage system or poured in any other place that prevents its collection or poses a risk of contamination of the soil and water.

Washing and rinsing the tank and the liquid sprayer installation should be carried out at a safe distance (no less than 30 m) from wells, water intakes and reservoirs and watercourses.

Procedure for rinsing the tank and liquid system

- Use the least necessary amount of water for rinsing (2–10 % of the volume of the tank or an amount that dilutes liquid remaining in the tank up to 10 times); it is recommended to rinse the liquid system with a small portion of water three times.
- Turn on the pump and rinse all the elements of the liquid system used during the procedure.
- Spray the rinsings on previously sprayed surface or, if it is not possible, use the residues according to the recommendations on the management of liquid residues.
- The remaining liquid drained from the sprayer should be disposed of using technical devices ensuring biological biodegradation of active substances of plant protection products. Until neutralisation or disposal, liquid residues may be stored in a sealed, labelled and secured container earmarked for that purpose.

External sprayer washing

After the end of the working day, wash all the apparatus from the outside with water, as well as components in contact with chemical agents. External washing of the sprayer should be carried out at a location that allows the washings to be directed into a closed collection system for contaminated residues or into a neutralisation/bioremediation system (e.g. Biobed, Phytobac, Vertibac station); if this is not possible, the sprayer should preferably be washed in the field. Wash the sprayer with a small amount of water, preferably using a high-pressure lance instead of a brush to shorten the time and increase the efficiency of external washing. Use recommended, biodegradable means to increase washing efficiency.

Recording of treatments

Professional users of plant protection products are required to maintain and keep records of their plant protection products for three years. The documentation should contain information on:

- the names of the plant protection product,
- the date of application,
- the dose used,
- the area and crops on which the protective treatment has been carried out,
- reasons for the treatment with a plant protection product.

Legislation also requires the method of fulfilling the requirements of integrated plant protection to be indicated in the documentation by providing at least the reason for treatment with a plant protection product. **Filling out the IP Notebook, mandatory under**

the integrated plant production scheme, fulfils the requirement to keep the above-mentioned documentation for certified crops.

10. HEALTH AND HYGIENE RULES

Personal hygiene of workers

Persons working in the harvesting and preparation of crop for sale should:

a) not be infected with or suffer from food-borne diseases;
b) maintain personal cleanliness, obey the rules of hygiene, and in particular often wash hands during work;
c) wear clean clothes and, where necessary, protective clothing;
d) cover wounds and skin abrasions with a waterproof dressing.

The producer shall ensure persons involved in harvesting crops and preparing them for sale:

a) unlimited access to washbasins and toilets, cleaning products, paper towels or hand dryers, etc.;
b) have undergone hygiene training.

Hygiene requirements for crops prepared for sale

The plant producer must take appropriate measures to ensure that:

a) that clean or consumption-class water is used to wash the crops as necessary;
b) during and after harvesting, the crops are protected against physical, chemical, and biological pollution.

Integrated plant production hygiene requirements for packaging, means of transport and places for the preparation of crops for sale

Under integrated plant production, the producer takes the necessary actions to ensure that:

a) cleanliness of rooms (and equipment), means of transport and packages is maintained;
b) farmed and domestic animals have no access to the rooms, vehicles or packaging;
c) harmful organisms (pests and organisms hazardous to humans), that may cause contamination or threat to human health, e.g. mycotoxins, are eliminated;
d) hazardous waste and substances are not stored together with crops prepared for sale.

11. PREPARATION FOR HARVESTING, HARVEST, AND POST-HARVEST PROCEDURE

The basic condition for starting mustard harvesting is that the plants reach adequate maturity. The second principle of rational harvest is to terminate it within a short period of

time. Extending the time of harvesting promotes the cracking of husks and the falling of seeds.

The preparation of mustard plantations for harvesting consists in eliminating weeds and aligning the ripening of plants in the crop. If high weed infestation prevents harvest or where agronomic or weather conditions make it impossible to achieve the homogeneous stage of ripeness of the plants for harvesting naturally, a desiccation treatment may be carried out. However, in general, chemical desiccation of plantations is not recommended with a view to achieving homogeneous ripeness, as it contributes to the contamination of seeds with desiccating agents and weakens their germination capacity.

Harvest period

White mustard should be harvested when fully mature. At this stage of ripeness, the stems and leaves are already dead, the husks, after yellowing, are brown, and the seeds are hard, yellow in colour. After shaking, the seeds rattle in the pod. The moisture content of the grain at this point is around 10 %, and this state of ripeness is reached after approximately four months of growth. Depending on the date of sowing and weather conditions, the harvesting period lasts from August to September, but most often falls in the first half of August. Delaying the start of harvesting too long causes the pods to crack.

When harvesting mustard seeds, however, the most important factor is their humidity, which should be below 10 %, and preferably about 8 %. Humidity above 10 % increases the risk of stored seeds moulding, which reduces their commercial germination value. However, too low moisture content of seeds can cause increased damage during threshing. Therefore, the parameters for the operation of the threshing unit—the peripheral speed of the drum and the size of the threshing gap—should be selected very carefully.

Harvest

During harvesting, special care must be taken to obtain seeds of a quality that allows them to be stored for a long period of time. Mustards, like rapeseed, are harvested in one or two stages. White mustard, not infested by weeds and evenly ripened, is harvested in a one-step method because its husks are more resistant to spontaneous opening than rapeseed. White mustard is also less sensitive to hail or heavy rain. On the other hand, delicate stems are prone to lodging, which makes harvesting difficult and causes seed losses. In the case of brown mustard and fast-ripening black mustard, which are rarely grown in our country and whose husks are susceptible to opening, a two-stage method should be used. A one-stage harvest of these mustards can be carried out in the morning, when the husks, thanks to the morning dew, are flexible and less prone to cracking.

The second factor influencing the selection of the harvest method is the state of the plantation. If plantations are weed-infested or fertilised with nitrogen, regardless of the mustard species, harvesting in two stages is recommended. The plants are mown at technical maturity when the straw is yellow and about 70 % of the seeds, depending on the species, are yellow or brown. After drying the swath, which in sunny weather on a high

stubble occurs takes 5–7 days, and when the seeds reach a moisture content of less than 10 %, one can start harvesting. Currently, the two-stage technology is used by a few manufacturers.

Preparation of the harvester for mustard harvesting requires its adaptation with the use of additional equipment and selection of appropriate operating parameters of the threshing unit and cleaning system. The adaptation of the harvester consists in the use of a harvesting unit, adapted for the harvesting of rapeseed, or in the lengthening of the floor of the harvesting unit and the installation of active crop splitters, in the adaptation of the cleaning unit, including the replacement of the strip screen with sieves with holes of a diameter of 3.5–4 mm and, if necessary, the installation of lifts of lodged plants.

The harvester must be adjusted in accordance with the operating instructions for mustard. The setting values given in the instructions should be considered as starting values and finally determined on the basis of the quality of the threshed seeds. In particular, it is important to adapt the threshing and cleaning unit parameters to the seed size characteristic of the mustard species. In the case of the threshing of white mustard, characterised by large seeds, the speed settings of the threshing drum and fan are similar to those of rapeseed threshing. When threshing brown and black mustard seeds, account should be taken of the much lower weight of the seeds. This requires setting the appropriate fan speed to reduce losses caused by blowing small seeds off and selecting sieves with correspondingly smaller slots or holes.

Harvest organisation

When organising the work of the harvester, one should try to make sure that the harvester moves along the patches, in a direction parallel to the crop rows orientation. Large fields should be divided into strips. The width of the first strip should be ten times the size of the working width of the harvester, and the subsequent strips: 20 times. When harvesting inclined and lodged plants, the direction of harvester movement must be adjusted to the direction of plant lodging.

The means of transport for the collection of seeds from the harvester should enable them to be quickly unloaded by means of a hydraulic tilting of the load platform. The cargo boxes of means of transport must be sealed and prepared for the transport of small grain. Inadequate preparation of the trailer, e.g. inaccurately closing sides or gaps in side/floor contact point, leads to large grain losses.

Storage

Only ripe, healthy, unheated, undamaged and cleaned seeds keep well. Mustard seeds intended for food production should have a moisture content of 6–7 %, a colour typical of mature seeds, no foreign odours, and the maximum share of usable dockage must not exceed 4 %, and 2 % for unusable dockage.

After harvesting, the seeds contain a lot of organic and inorganic impurities and their moisture content often does not allow them to be stored directly. The seeds undergo intensive biochemical transformations of post-harvest maturation. As a result of 'seed sweating', the process of self-heating and infestation by mould fungi may occur. The self-heating process of seeds can also be a consequence of their contamination with organic residues such as straw, husks, damaged seeds, weed seeds and green parts of weeds. Therefore, immediately after harvesting, the seeds should first be cleaned and then dried to a moisture content of 5–7 %. Seeds should be dried in such a way that their germination capacity is not destroyed. Dry seeds can be stored in cool and dry conditions for several years.

12. DEVELOPMENTAL STAGES OF MUSTARD BASED ON THE BBCH SCALE

The BBCH scale is becoming more and more frequently used to determine the precise crop growth stages. It is appreciated by advisers and plant producers, primarily for its universality, because for all crops the same division of phenological phases has been used, and complex descriptions were replaced by suitable number codes. The standard description of the development phases according to the BBCH has the same code, regardless of the language and country in which the scale is used. The two-digit code precisely determines the current growth stage of the plant. The first digit always determines the principal growth stage, and the second enables an even more precise determination of the growth stage and development of the crop. Arithmetically higher code indicates a later developmental phase (Matysiak and Strażyński 2018).

Mustard (*Sinapis* L.) is an annual plant of the Brassicae family. In Poland, three species of mustard are of economic importance: white mustard (S. *alba* L.), black mustard (S. *nigra* L.) and brown mustard (S.*juncea* L.). The length of the growing period for mustard, depending on its target use, is between 70 and 120 days. Mustard height is a characteristic of individual species and can range from 50 cm (white mustard and brown mustard) to 150 cm (black mustard).

On the BBCH scale, 9 main development phases of mustard have been set out: 0 — Germination, 1 — Leaf development, 2 — Formation of side shoots, 3 — Main shoot elongation, 5 — Flower bud development, 6 — Flowering, 7 — Fruit development, 8 — Fruit ripening, 9 — Senescence. First mustard emergence occurs already after 5 days. The habitat and water requirements differ from one species to another. However, white mustard, which has the most extensive root system, is sensitive to water scarcity. The flowering period in mustard lasts between 3 and 6 weeks. The size and colouring of mustard seeds are species-specific characteristics.

Note: Plants on a given plantation may be in different stages of growth.

CODE DESCRIPTION

Principal growth stage 0: Germination

00 Dry seed
01 Beginning of seed imbibition
03 Seed imbibition complete
05 Radicle has emerged from seed
07 Hypocotyl with cotyledons emerged from seed
08 Hypocotyl with cotyledons growing towards surface
09 Cotyledons emerge through soil surface

Principal growth stage 1: Leaf development

10 Cotyledons fully unfolded
11 First true leaf unfolded
12 Second true leaf unfolded
13 Third true leaf unfolded
1. Stages continue until…
19 Nine or more true leaves unfolded

Principal growth stage 2: Formation of side shoots

20 No side shoots
21 The beginning of the development of side shoots, the first side shoot detectable
22 Developed two side shoots
23 Developed three side shoots
2. Stages continue until…
29 End of side shoot formation phase

Principal growth stage 3: Main shoot elongation

30 Beginning of stem elongation
31 First internode visible
32 Second internode visible
33 Third internode visible
3. Stages continue till…
39 Nine or more internodes visible

Principal growth stage 5: Development of flower buds (budding)

50 Flower buds present, still enclosed by leaves
51 Flower buds visible from above (‘green bud’)
55 Single flower buds (main inflorescence) visible, still closed
57 Individual flower buds (secondary inflorescences) visible but still closed
59 First petals visible, flower buds still closed

Principal growth stage 6: Flowering

60 First flowers open
61 10 % of flowers on main raceme open, main raceme elongating
62 20 % of flowers on main raceme open
63 30 % of flowers on main raceme open
64 40 % of flowers on main raceme open

65 Full flowering: 50 % flowers on main raceme open, older petals falling
67 Flowering declining: majority of petals fallen
69 End of flowering

Principal growth stage 7: Development of fruit
71 10 % of pods have reached final size
72 20 % of pods have reached final size
73 30 % of pods have reached final size
74 40 % of pods have reached final size
75 50 % of pods have reached final size
76 60 % of pods have reached final size
77 70 % of pods have reached final size
78 80 % of pods have reached final size
79 Nearly all pods have reached final size

Principal growth stage 8: Ripening of the fruits

80 Beginning of ripening: green seeds, filling the cavities in the pod
81 10 % of pods ripe, seeds colour and harden
83 30 % of pods ripe, seeds yellow, brown or black and hard
85 50 % of pods ripe, seeds yellow, brown or black and hard
87 70 % of pods ripe, seeds yellow, brown or black and hard

Principal growth stage 9: Senescence
97 Plant dead and dry
99 Harvested product, dormancy

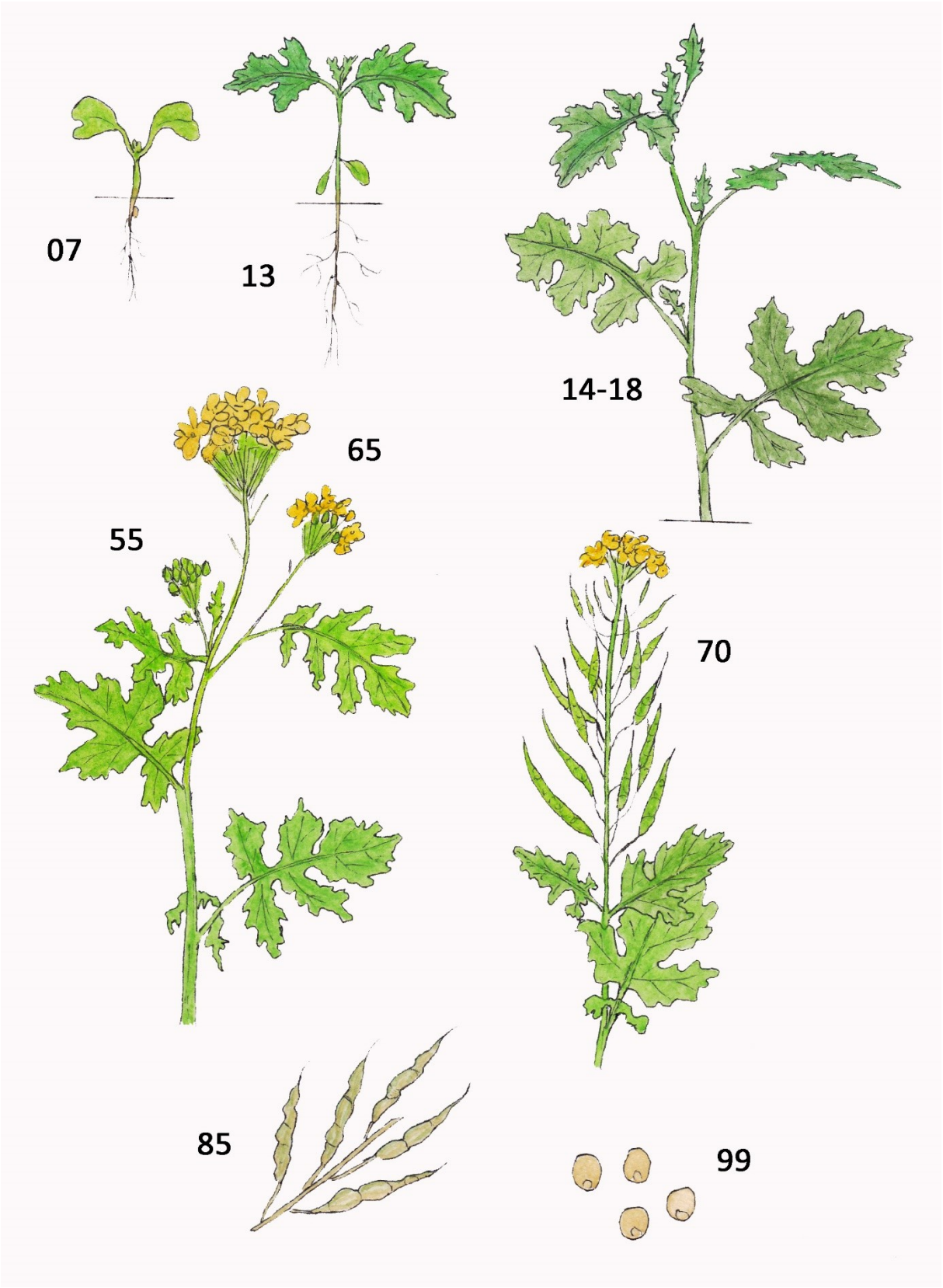

Fig. P. Strażyński

13. RULES FOR KEEPING RECORDS IN INTEGRATED PRODUCTION

The cultivation of plants under the integrated plant production system is inextricably linked to the keeping or possession of various types of documentation by the agricultural producer. The IP Notebook is one of the most important of such documents. Model notebooks are included in the Annex to Regulation of the Minister for Agriculture and Rural Development of 24 June 2013 on documenting activities related to integrated plant production (consolidated text: Journal of Laws 2023, item 2501). The record-keeping rules will change on 1 January 2026 as a result of the application of Implementing Regulation (EU) 2023/564.

Other documents that an integrated plant producer must possess or may have to deal with during the certification process include:

- the methodology of integrated plant production;
- the notification of accession to integrated plant production;
- the certificate of the registration number;
- programme or conditions for certification of integrated plant production;
- the price list for the certification of integrated plant production;
- the contract between the agricultural producer and the certification body;
- rules for dealing with appeals and complaints;
- information on GDPR;
- lists of plant protection products for IP;
- inspection reports;
- checklists;
- test results on residues of plant protection products and levels of nitrates, nitrites and heavy metals in agricultural crops;
- soil and leaf test results;
- certificates of completion of training;
- reports or proof of purchase attesting to the technical functioning of the equipment for applying plant protection products;
- purchase invoices for, among others, plant protection products and fertilisers;
- application for a certificate;
- IP certification.

The certification process begins with the completion and submission, within the statutory deadline, of the application for integrated plant production by the producer to the certification body. A model application may be obtained from the certification body or downloaded from its website.

The application form should be completed with information such as:

- the name, surname and address and place of residence or the name, address and registered office of the plant producer;

- the PESEL (personal identification) number, if one has been assigned to them.

The application must also include the date and signature of the applicant. The application shall be accompanied by information on the species and varieties of plants to be grown under the IP system and the location and area of their cultivation. A copy of the certificate of completion of training in integrated plant production or a copy of the certificate or copies of other documents attesting to the qualification must also be attached to the application.

During cultivation, the agricultural producer is obliged to keep records of activities related to integrated plant production in the IP notebook on an ongoing basis. The type of notebook is chosen according to the species of crop that has been declared to the certification body. When applying for certification for more than one plant species, IP Notebooks must be kept individually for each crop.

The Notebook should be filled out according to the following outline.

Cover — the plant species and the year of cultivation as well as the number in the plant producers' register should be stated on the cover. Next, own information must be added.

Inventory of fields/plots/greenhouses/tunnels in the integrated production system — in the table with the list of fields, all cultivated varieties submitted for IP certification must be recorded.

Field plan with biodiversity-increasing elements — graphically reproduce the plan of the farm and its immediate surroundings with the proportions of the given elements. The holding plan uses the same markings as those used in the field inventory.

General information, sprayers, operators — the year in which production according to the principles of Integrated Plant Production was started is to be recorded. Then, the tables must be filled in. The bullet points should be filled in with appropriate entries and the information confirmed by ticking the relevant boxes ( ). The 'Sprayers' table should be filled in with the required data and the information confirmed by ticking the relevant boxes (□). List all sprayer operators carrying out plant protection treatments in the 'Sprayer operator(s)' table. It is absolutely necessary to indicate that the training in the use of plant protection products is up to date, including the date of completion (or other qualification). List all devices and persons performing treatments, including those performed by a service provider, in the 'Sprayers' and 'Sprayer operator(s)' tables.

Purchased plant protection products — the purchased plant protection products (trade name and quantity) intended to protect the crop for which the Notebook is kept must be recorded in the table.

Monitoring tools, e.g. colour sticky boards, pheromone traps - in the table, record the used colour sticky boards, pheromone traps, etc. and indicate pests which these tools were intended to monitor.

Crop rotation — the crop rotation table should be filled in with the crop and the code of the field on which it was cultivated. Crop rotations must be reported for the period (number of years) specified in the methodology.

Seed (...) — the table should be filled in with information about the purchased seed: its species, variety, category, degree of qualification, quantity, and proof of purchase (invoice, official label — plant passport).

Sowing/planting — the table should be filled in with the recorded quantity of seed material used in each field. The dates of the activities carried out should also be recorded. For this purpose, tick the relevant boxes (□) to confirm the information on soil testing/assessment for existing pests which would exclude the field from IP cultivation.

Soil/substrate and plant analysis and fertilisation/fertigation — soil analysis is a fundamental activity to determine the fertiliser needs of plants. A producer growing crops in the IP system must perform such analyses and record them in a notebook. Enter the field code, the type or scope of testing and the number and date of the report in the 'Soil and plant analysis' table. Record all organic fertilisers applied in the 'Organic fertilisation (...)' table. If green manures are used, the species or composition of the mixture is indicated in the 'Type of fertiliser' column. In the next table, 'Mineral soil fertilisation and liming,' record the date, type and dose of fertilisation and liming used and the place of its application. The table 'Observations of physiological disorders and foliar fertilisation' is a record of observations of plant nutritional deficiencies and constitutes a register of fertilisers used. The IP grower must regularly inspect the crops for the occurrence of physiological diseases and record this fact each time. Foliar fertilisation should be correlated with the observations of physiological disorders carried out.

Control observations and record of plant protection treatments — the plant protection tables are the key element of the IP Notebook. The first table 'Observations of weather conditions and plant health' is a detailed record of observations made, in which the data indicated in the heading should be recorded. The need for chemical treatment should also be indicated in this table. The next two tables are registers of plant protection treatments (agronomic, biological and chemical) and are closely correlated with the observation table. When carrying out this type of procedure, it is mandatory to record the name of the plant protection product or the biological or agronomic method applied, as well as the date and place of treatment. The table 'Other chemical treatments applied (...)' is a record of all treatments authorised for the crop that are not listed in the previous tables, e.g. desiccants.

Harvest — in this table, record the volume of crop taken from each field.

Hygiene and health requirements — record whether people in direct contact with food have access to clean toilets and hand-washing facilities, cleaning products, and paper towels or hand dryers. Also the manner of observing the hygiene and health requirements for IP methodologies should be described.

Other mandatory requirements for the protection of plants against pests according to the requirements of the integrated production methodology — a page in the Notebook containing space for IP producer's comment concerning requirements for plant protection against pests set out in the integrated plant production methodologies.

Information on the cleaning of machinery, devices and equipment used in production, according to the requirements of the integrated production methodology — Notebook page intended for the IP producer's information relating to the cleaning of machinery, devices and equipment used in the production, which is required under the integrated production methodology.

The Notebook also contains space for comments and own notes, and a list of appendices.

It is possible for an agricultural producer to obtain an IP certificate by applying to a certification body. Forms for the relevant applications are available from the certification bodies. Along with the completed application for a certificate certifying the use of integrated plant production, the plant producer shall provide the certifying entity with a statement that the cultivation was carried out in accordance with the requirements of integrated plant production and information on the species and varieties of plants grown using the requirements of integrated plant production, the area of their cultivation and the yield size.

14. LIST OF MANDATORY ACTIVITIES AND PROCEDURES IN INTEGRATED PRODUCTION (IP) OF MUSTARD

Mandatory requirements (100% compliance, i.e. 11 points)			
Item	**Control points**	**YES/NO**	**Comment**
1.	The use of at least a 3-year break in brassica cultivation on the same site (**see Chapter 3.3**).	□/□	
2.	Selection of varieties recommended by the RCFCT (**see Chapter 4**)	□/□	
3.	Application of pre-sowing crop treatments according to the methodology (**see Chapter 5.1**).	□/□	
4.	Macro- and micronutrient fertilisation based on	□/□	

	nutrient balance analysis (**see Chapter 6).**		
5.	Use of mechanical methods in pre- and post-emergence weed control (**see chapter 7.1.2).**	□/□	
6.	Systematic monitoring from emergence to the beginning of maturation, at least 1x per week, for diseases such as clubroot, cabbage black leaf spot, fungal rot, grey mould, white rust (**see Chapter 7.2.1**).	□/□	
7.	Systematic monitoring from the time of emergence to the beginning of maturation, at least 1x per week, of the presence of pests, i.e. turnip sawfly, common pollen beetle, cabbage gall weevil and brassica pod midge, using appropriate methods (see **Chapters 7.3.1., 7.3.2**).	□/□	
8.	Performance of at least one pest control treatment with a biological control product, if one is registered (**see Chapter 8**).	□/□	
9.	Creating the right conditions for the presence of birds of prey, i.e. setting up resting poles at a frequency of at least 1 for every 5 ha of plantation (**see Chapter 8).**	□/□	
10.	Placing of 'houses' for mason bees or mounds for bumblebees or other facilities for insect pollinators in the amount of at least 1 pc for every 5 ha (**see Chapter 8).**	□/□	
11.	Shredding and ploughing of post-harvest residues after harvest (**see chapter 7.3.3).**	□/□	

Note: The fulfilment of all the requirements in the list of mandatory activities and treatments under the integrated production system must be documented in the Integrated Plant Production Notebook.

15. CHECKLIST FOR AGRICULTURAL CROPS

Basic requirements (100% compliance, i.e. 28 points)			
No.	Control points	YES/NO	Comment
1.	Does the producer produce and protect the crops according to detailed methodologies approved by the Main Inspector?	□/□	
2.	Does the producer have up-to-date IP training confirmed by a certificate, subject to Articles 64(4), (5), (7) and (8) of the Plant Protection Products Act?	□/□	
3.	Does the producer apply plant protection products only from the list of IP-recommended products?	□/□	
4.	Are all required documents (e.g. methodologies, notebooks) present and kept on the farm?	□/□	
5.	Is the IP Notebook kept correctly and up to date?	□/□	
6.	Does the producer systematically conduct control observations of the crops and record them in the Notebook?	□/□	
7.	Does the producer deal with empty packaging of crop protection products and products that are expired in accordance with the applicable legal regulations?	□/□	
8.	Is chemical protection of crops replaced by alternative methods wherever justified?	□/□	
9.	Is chemical plant protection carried out based on risk thresholds and the alerting of harmful organisms (wherever possible)?	□/□	
10.	Are plant protection product treatments carried out only by persons holding an up-to-date, as of the date of such treatments, certificate attesting to the completion of training in the scope of the application of plant protection products, advising on plant protection products or integrated plant production, or any other document confirming the permission to apply plant protection products?	□/□	
11.	Are the applied plant protection products approved for use in the given cultivation - plant?	□/□	
12.	Is each use of plant protection products recorded in the IP notebook taking into account the reason,	□/□	

Basic requirements (100% compliance, i.e. 28 points)			
	date and place of use, the area of the crops, the dosage of the preparation and the amount of the spray liquid per unit area?		
13.	Were the plant protection treatments carried out under appropriate conditions (optimal temperature, wind below 4 m/s)?	□/□	
14.	Is the rotation of the active substances of the crop protection products used for the treatments respected, if possible?	□/□	
15.	Does the producer limit the number of treatments and the amount of crop protection products used to a necessary minimum?	□/□	
16.	Does the producer have measuring devices to precisely determine the quantity of the measured plant protection agent?	□/□	
17.	Are the conditions for safe use of the products respected, as set out on the labels?	□/□	
18.	Does the producer comply with the provisions of the label concerning the observance of precautions related to environmental protection, i.e. e.g. the observance of protective zones and safe distances from areas not used for agricultural purposes?	□/□	
19.	Are prevention and withdrawal periods observed?	□/□	
20.	Are the doses and maximum number of treatments per growing season specified on the label of the plant protection product not exceeded?	□/□	
21.	Are the sprayers referred to in the IP notebook in good technical condition and are their technical inspection certificates up to date?	□/□	
22.	Does the producer carry out systematic calibration of the sprayer(s)?	□/□	
23.	Does the producer have a separate space for filling and cleaning the sprayers?	□/□	
24.	Does the handling of residues of the operating liquid comply with the indications on plant protection product labels?	□/□	
25.	Are plant protection products stored in an appropriately marked closed room in such a way as to prevent contamination of the environment?	□/□	

Basic requirements (100% compliance, i.e. 28 points)			
26.	Are all plant protection products stored only in their original packaging?	□/□	
27.	Does the IP producer comply with hygiene and sanitary rules during plant production, in particular those specified in the methodologies?	□/□	
28.	Are appropriate conditions for the development and protection of beneficial organisms ensured?	□/□	
	Total points		

Additional requirements for field vegetable crops (minimum compliance 50%, i.e. 8 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	Were the plant varieties grown selected for Integrated Plant Production?	□/□	
2.	Is each box marked according to the entry in the IP notebook?	□/□	
3.	Did the producer perform all the necessary agrotechnical procedures in accordance with IP methodologies?	□/□	
4.	Is the recommended catch crop used in cultivation?	□/□	
5.	Are steps taken on the holding to reduce soil erosion?	□/□	
6.	Have the procedures been conducted using spraying devices specified in the IP notebook?	□/□	
7.	Are fertiliser application machines maintained in good working order?	□/□	
8.	Do fertiliser application machines allow for accurate dose determination?	□/□	
9.	Is each fertiliser applied recorded with regard to its form, type, date of application, quantity, location and surface?	□/□	
10.	Are fertilisers stored in a separate and specially designated room in a manner that ensures protection of the environment against contamination?	□/□	
11.	Does the producer protect empty PPP packaging	□/□	

	against unauthorised access?		
12.	Does the producer have a dedicated place to collect organic and post-vegetable-sorting residues?	□/□	
13.	Are there first-aid kits near the workplace?	□/□	
14.	Are hazardous areas on the farm, e.g. plant protection product storage rooms, clearly marked?	□/□	
15.	Does the producer use consultancy services?	□/□	
	Total points		

Recommendations (min. implementation 20%, i.e. 2 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	Have soil maps been drawn up for the holding?	□/□	
2.	Are non-organic fertilisers stored in a clean and dry room?	□/□	
3.	Has a chemical analysis of organic fertilisers for nutrient content been carried out?	□/□	
4.	Does the lighting in the room where the plant protection products are stored make it possible to read the information on the packaging of the plant protection products?	□/□	
5.	Does the producer know how to proceed in the event of plant protection products spilling or scattering and do they have the tools to counteract such a threat?	□/□	
6.	Does the producer restrict access to the keys and warehouse in which plant protection products are stored only to persons who have the authority to use them?	□/□	
7.	Does the producer store on the holding only plant protection products allowed for use with the plant species they cultivate?	□/□	
8.	Does the producer deepen their knowledge through Integrated Plant Production meetings, courses or conferences?	□/□	
	Total points		

16. FURTHER READING

Budzyński W., Zając T. 2010. Rośliny oleiste, uprawa i zastosowanie. PWRiL, Poznań, 300 pp.

Fiedler Ż. 2007. [in:] 'Organizmy pożyteczne, występowanie, identyfikacja oraz wykorzystanie w integrowanej produkcji w Polsce'. (D. Sosnowska, red). 84 pp.

Hołubowicz-Kliza G., Mrówczyński M., Strażyński P. 2018. Szkodniki i organizmy pożyteczne w integrowanej ochronie roślin rolniczych. IUNG – PIB, Puławy, IOR– PIB, Poznań, 502, pp.

Jajor E., Mrówczyński M., Bartkowiak-Broda I., Broniarz J., Danielewicz J., Dworzańska D., Fiedler Ż., Gorzała G., Horoszkiewicz-Janka J., Kierzek R., Korbas M., Matyjaszczyk E., Matysiak K., Nijak K., Obst A., Perek A., Paradowski A., Pruszyński G., Strażyński P., Wachowiak H., Węgorek P., Wielebski F., Wójtowicz M., Zamojska J. 2017. Metodyka integrowanej ochrony gorczycy dla doradców (E. Jajor, M. Mrówczyński, red.). IOR – PIB, Poznań, 174 pp.

Jasińska Z., Kotecki A. 2003. Szczegółowa uprawa roślin. Wydawnictwo AR, Wrocław, 510 pp.

Kierzek R., Wachowiak M., Ratajkiewicz H. 2012. Rola techniki i precyzji zabiegów w integrowanych systemach ochrony roślin. 10th 'Racjonalna Technika Ochrony Roślin' Conference materials. Poznań, 14–15.11.2012. p. 152–160.

Korbas M., Horoszkiewicz-Janka J., Jajor E. 2008. Uproszczone systemy uprawy a występowanie sprawców chorób. Progress in Plant Protection/Postępy w Ochronie Roślin 48(4): 1431–1438.

Kryczyński S., Weber Z. (red.). 2011. Fitopatologia. Volume 2. Choroby roślin uprawnych. PWRiL, Poznań, 464 pp.

Muśnicki Cz. 1999. Rośliny oleiste. Gorczyca. pp. 439–446. [in:] 'Szczegółowa uprawa roślin' (Z. Jasińska, A. Kotecki, red.). Akademia Rolnicza, Wrocław, vol 2, 679 ss.

Matysiak K., Strażyński P. 2018. Fazy wzrostu i rozwoju wybranych gatunków roślin uprawnych i chwastów według skali BBCH. Institute for Plant Protection — State Research Institute, Poznań, 184 pp.

Mrówczyński M., Czubiński T., Klejdysz T., Kubasik W., Pruszyński G., Strażyński P., Wachowiak H. 2017. Atlas szkodników roślin rolniczych dla praktyków. PWR, 368 pp.

Nowakowski M. 2013. Przydatność gorczycy białej i rzodkwi oleistej jako mulczu, nawozu i czynnika ochrony fitosanitarnej w uprawie buraka cukrowego. Monografie i Rozprawy Naukowe IHAR-PIB 43, 144 pp.

Paradowski A. 2013. Atlas chwastów. Plantpress, Kraków, 232 pp.

Paradowski A. 2015. Atlas chwastów roślin rolniczych, sadowniczych i warzywnych. Hortpress, Warszawa, 208 pp.

Paszkiewicz-Jasińska A. 2005. Wpływ wybranych czynników agrotechnicznych na rozwój gorczycy białej, plon i jego jakość. I. Wpływ nawożenia azotem i gęstości wysiewu na rozwój i plonowanie gorczycy białej (*Sinapis alba* L.). Rośliny Oleiste-Oilseed Crops XXVI (2): 451–465.

Pusz W., Serafin-Andrzejewska M., Pląskowska E., Kozak M. 2012. Wpływ zróżnicowania nawożenia siarką na zdrowotność nasion gorczycy białej, odmiany Radena. PPPR 52(3): 590–593.

Sawicka B., Kotiuk E. 2007. Gorczyce jako rośliny wielofunkcyjne. Acta Scientiarum Polonorum, Agricultura 6(2): 17–27.

Sosnowska D., Fiedler Ż. 2013. Metody biologiczne i ochrona organizmów pożytecznych. pp. 45–59. [in:] 'Integrowana ochrona upraw rolniczych' volume 1. Podstawy integrowanej ochrony (Marek Mrówczyński, red.). PWRiL, Poznań, 153 pp.

Toboła P. 2010. Gorczyce – biała, sarepska, czarna. pp. 109–124. [in:] 'Rośliny oleiste – uprawa i zastosowanie' (W. Budzyński, T. Zając, ed.). PWRiL, Poznań, 300 pp.

Tratwal A., Strażyński P., Bereś P.K., Korbas M., Danielewicz J., Jajor E., Horoszkiewicz-Janka J., Jakubowska M., Roik K., Baran M., Wielkopolan B., Kubasik W., Klejdysz T., Węgorek P., Zamojska J., Dworzańska D., Barłóg P., Jaskulska M., Dobosz R. 2018. Poradnik sygnalizatora ochrony rzepaku (A. Tratwal, P. Strażyński, M. Mrówczyński, red.) IOR–PIB Poznań, 205 pp.