MAIN INSPECTORATE FOR PLANT HEALTH AND SEED INSPECTION

Methodology for the Integrated Production of barley (*Hordeum vulgare* L.) of the brewing type

(second edition supplemented)

DRAFT

Approved
pursuant to Article 57(2)(2) of the Act of 8 March 2013 on plant protection products
(consolidated text: Dz.U. of 2024, item 630)

by

the Main Inspector of Plant Health and Seed Inspection

INTEGROWANA PRODUKCJA
URZĘDOWO KONTROLOWANA
INTEGRATED PRODUCTION
OFFICIALLY CONTROLLED

Approved by

~~/signed electronically/~~

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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. Natural biological mechanisms supported by the rational use of plant protection products are used under the integrated plant production scheme as much as possible. 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, with a view to creating 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 PROVISIONS APPLICABLE IN THE 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 health, animals and the environment.

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 combat 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 (Dz.U. of 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 (Dz.U. of 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. The law 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 the 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 under the integrated plant production scheme and obtaining an IP certificate is to submit a notification to the body certifying integrated plant production.

The notification of the intention to use integrated plant production must be made annually by the plant producer concerned to the certification body, within the time limit laid down in Article 55(2) of the Act of 8 March 2013 on plant protection products. The integrated plant production scheme is open to all producers. Notification of the intention to participate in the scheme may be submitted on paper by post, electronically, or in person.

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 (Dz.U. 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. The producer shall be certified if it has complied with the following requirements:

- has completed training in integrated plant production and holds a certificate of completion of that training, subject to Article 64(4), (5), (7) and (8) of the Plant Protection Products Act;
- grow and protect plants in line with the detailed methodology approved by the Main Inspector and made 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;
- follows hygienic and sanitary rules in plant production, particularly those defined in methodologies;
- in plant and plant product samples collected for testing, no maximum permissible residues of plant protection products and levels of nitrates, nitrites and heavy metals have been exceeded;
- they adhere to requirements concerning plant protection against harmful organisms, particularly those specified in 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

In addition to the genetic factor (choice of the right variety), the yield of brewing barley is strongly influenced by climate, soil and agrotechnical conditions. Barley is less sensitive to limiting climatic factors (rainfall deficiency, large temperature fluctuations) and therefore has, among spring cereals, a higher yield reliability. Barley has the advantage of being the most drought resistant (compared to other cereals) due to its lower transpiration rate.

During the growing period of barley, an even distribution of rainfall is important in order to ensure a high yield of grain, with low protein content in the grain. The brewing value of barley is negatively affected by prolonged drought and high temperature during the growing season, because in addition to a reduction in grain yield (as a result of reduced mineral intake) the protein and husk content of the grain increases, while grain accuracy and malt extractability is reduced. Under such conditions, there is a reduction in the conversion of sucrose to starch, leading to an increase in protein content due to a reduction in carbohydrate content, and the reduction in grain size is accompanied by an increase in husk content.

Spring barley has a different growth dynamic than winter barley. The impact of rainfall on yields during the period from sowing to tillering is very important. Optimal rainfall during this period should be about 12 mm every 10 days. A critical period is considered to be the to be the stalk shooting and earing phase, where the optimal rainfall increases to 20–23 mm every 10 days. However, so-called atmospheric droughts are most dangerous, especially on soils of rye complexes, from 10 days before the earing phase and about 10 days afterwards.

In the case of winter barley, its development is best when the precipitation from sowing barley to inhibiting vegetation is between 70 and 90 mm. Wet autumn is not conducive to hardening plants and worsens wintering. A strong vegetative growth before winter can promote the infestation of real grains and grasses by the culprit of powdery mildew and facilitates displacement. In the event of severe temperature reductions below 0 °C, the protective role of snow is important. The sensitivity of winter barley to atmospheric droughts is lower than other winters.

For spring barley, the optimal temperature during the emergence period should be 5–7°C, and around 8°C during the tillering phase, which contributes to productive tillering. The optimum temperature during the stalk shooting stage of barley should be 12–15 °C, and often natural environment conditions are such that the temperature is much higher. After the earing phase, optimal barley thermal conditions increase to 16.5 °C. The strongest yield-forming effect is exerted by temperature changes occurring from the earing phase to wax maturity of barley; usually the temperature occurring during this period is higher than desired.

The effect of the temperature on the condition of barley plants prior to winter is less than precipitation. An early cessation of the vegetation development typically results in poorer overwintering capacity. The greater the influence of the continental climate during the wintering period of winter barley, the greater the threat to its winter hardiness it is.

3.1. Site

Climatic conditions in Poland allow the cultivation of spring and winter brewing barley on the territory of the country. The spring form of brewing barley is of a greater economic importance. However, there are conditions for the suitability of variety cultivation in specific areas of the country, due to the varietal tolerance for limiting factors e.g. water stress, susceptibility to diseases, lodging, etc.

The biggest drawback of winter barley is its relatively low resistance to freezing (winter resistance 4.0), which is a limitation in some areas of the country. Winter barley is the least resistant to frost from all cereals grown in Poland, and the assessments of varieties in COBORU (Research Centre for Cultivar Testing) studies are incomparable to those of winter wheat and winter triticale varieties (milder criteria for treating barley). However, the current climate changes favour the cultivation of winter barley and reduce the risk of losses.

Growing brewing barley is more difficult than other types of barley use and is therefore only likely to be successful on farms where good agricultural practices are implemented.

The sowing of brewing barley in crop rotations that leave significant amounts of nitrogen in the soil and in cereal monoculture should be avoided.

3.2. Soil

Barley has quite high soil requirements (higher than oats, triticale and rye), due to its less developed root system and short growing season. Brewing barley has higher soil and precursor crop requirements.

The highest yields are obtained on clay or silty soils. These are usually made up of wheat complex soils (very good and good). Smaller but satisfactory yields can also be obtained on lighter soils (loamy sands), with more compact soil, belonging to the very good and good rye complex, provided that a high level of cultivation is maintained.

The relationship between soil quality and yield of winter barley is not unconditional, but mainly modified by the weather (especially the amount and distribution of precipitation during vegetation).

Among cereals, barley has the highest sensitivity to acidic soil pH and should be grown at a soil pH above 5.5 when it comes to lighter soils and above 6.0 when it comes to firmer soils. The decrease in barley yield on acidic soils is due to its high sensitivity to excess free aluminium ions and manganese.

3.3. Pre-crop

Very good pre-crops for spring brewing barley are root crops: sugar beet and fodder beet, and tuber root crops – potatoes. Good pre-crops are winter and spring rape, maize – silage and grain, sunflower, sorghum, buckwheat, vegetables (however, attention should be paid to the nutrient balance in the soil so that the amount of nutrients after vegetables is suitable for growing spring barley for brewing purposes).

The worst pre-crops after which it is not allowed to grow spring barley for brewing purposes are all beards and cereals. Brewing barley should not be cultivated after leguminous crops, which leave excessive amounts of nitrogen in the soil, thereby increasing the risk of lodging, reducing grain uniformity, and resulting in protein accumulation in the grain exceeding 12%. As far as cereals are concerned, the exception is oats, which does not create good conditions for the development of pathogenic barley fungi. Therefore, oats are allowed as a pre-harvest for spring barley intended for brewing purposes grown in an integrated production system. A break of at least 3 years in the cultivation of barley after each other and after other cereal plants (excluding oats) is required.

For winter brewing barley, the best pre-crops are root crops and tuber early potatoes. Good pre-crops include winter and spring oilseed rape, silage maize and sorghum (provided that the date of their harvest will allow proper preparation of the site and timely sowing, if not they can not be pre-harvested for winter barley grown for brewing purposes in the IP system), vegetables (provided that the date of their harvest will allow proper preparation of the site and timely sowing, if not they can not be pre-harvested for winter barley grown for brewing purposes in the IP system). Attention should also be paid to the nutrient balance in the soil, so that the amount of nutrients after vegetables is appropriate for growing spring barley intended for brewing purposes.

The worst pre-crops, after which winter barley intended for brewing purposes must not be cultivated, are all leguminous plants and cereals. The exception is oats, which does not create good conditions for the development of pathogenic barley fungi. Therefore, oats are allowed as a pre-crop for winter brewing barley grown in an integrated production system. The worst pre-crops also include sugar beets, late potatoes and industrial potatoes, maize cultivated for grain, sunflower.

4. SELECTION OF BREWING BARLEY VARIETIES IN INTEGRATED PRODUCTION

The main objective of growing brewing barley is to obtain a high-quality raw material that meets the requirements of the malting plant. Quality is influenced by a number of factors, and one of the most important is the choice of the appropriate variety. Therefore, malting plants decide which varieties to grow and contract only the best and proven by themselves. Often they even supply their seed. The corresponding agro-technique, which is different for the cultivation of varieties of the brewing type and fodder type, is also very important.

In the second place, attention should be paid to the variety's yield, healthiness or resistance to lodging. Varieties of spring barley and winter barley are tested at the Central Centre for the Testing of Cultivated Varieties (COBORU) at 51 experimental sites located throughout the country. As a result, objective data are obtained on the most important performance characteristics and agrotechnical requirements of different varieties.

Varieties intended for brewing purposes must be characterised by high technological value, which includes the quality parameters of both malt and wort. The brewing value of barley varieties is assessed based on five characteristics: extract content, Kolbach index, diastatic power, final wort attenuation, and wort viscosity, with extract content being the most critical parameter. The higher the brewing value of the variety, the greater its suitability for malt production. Grain characteristics are also very important: protein content, which should be within the range of 9.5% to 11.5% DM, grain density, one-thousand-grain weight, and uniformity.

Every year, new, valuable creations are registered in COBORU, which make great progress in terms of fertility. In the past, good quality parameters were obtained at the expense of yield. Currently, it has been possible to combine quality with fertility and varieties of the brewery type often yield comparable or even higher than varieties of the fodder type. However, varieties of the brewing type registered in Poland come from foreign breeders, while fodder varieties are mostly from domestic breeding.

In COBORU experiments with barley, from which samples are taken for technological research, the nitrogen dose is limited to 40 kg/ha for the spring form and to 50 kg/ha for the winter form. Excess nitrogen contributes significantly to the deterioration of the malt quality and, consequently, to the turbidity of the beer.

If we have already selected and contracted a variety with high yields, good health and resistance to lodging, properly cultivated, we should obtain high-quality grain. The grain that the brewing plant buys must be healthy and undamaged, distinguished by germination energy above 96%. The grain must also be balanced and customs, with a protein content of between 9.5 and 11.5% and without impurities. Only this grain guarantees the production of high-quality malt.

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

5. PRE-SOWING TILLAGE AND SOWING

Rational soil cultivation should contribute to achieving optimum compaction of individual soil layers, improving soil structure, reducing soil water losses, and eliminating the negative consequences of pre-crop production technology. In addition, proper soil cultivation is aimed at reducing weeds, mixing precursor crop residues and natural and organic fertilisers with the soil, increasing the biological activity of the soil and reducing the severity of water and wind erosion.

5.1. Soil cultivation

Soil cultivation for brewing barley should be performed with extreme care, as barley is very sensitive to insufficient soil aeration and has higher requirements for soil plumpness.

In integrated barley production, it is advisable to carry out agrotechnical treatments to reduce weed infestation before sowing.

The cultivation of the winter barley is determined by the pre-crops. The simplifications in the barley cultivation system differentiate the yield in the range of 7-9%. It should be remembered that the late ploughing should be deep-rooted. Settlement of the soil only after the rising of winter barley exposes the propagation node, which exposes the plants to temperature fluctuations during winter. This contributes to a decrease in the intensity of propagation and weaker wintering.

In the IP brewing barley cultivation, all cropping systems with the exception of direct sowing (zero-tillage) are permitted.

Post-harvest and autumn cultivation

The possibility of growing spring barley after different precursor crops results in a diversity of cultivation methods. The vast majority of spring barley plantations are established after the cultivation of precursor crops that are harvested early from the field, which makes post-harvest cultivation necessary. The first procedure of traditional cultivation is ploughing. It is less efficient and more energy-consuming compared to the use of a pneumatic sowing machine (cultivator, levelling discs, string roller), which is recommended when it comes to integrated cultivation. In the absence of the pneumatic sowing machine, a stubble cultivator or a disc machine can be used. This treatment should be carried out as soon as the precursor crop has been harvested, at a depth of 6 to 9 cm. Its purpose is to cover the stubble, interrupt evaporation from the soil, cover the weed seeds and the precursor crop in order to encourage them to germinate, level, and reconsolidate the soil. The next procedure is harrowing after weeds and volunteer cereals have emerged in order to destroy them, to be repeated after each subsequent weed emergence has occurred. An alternative to post-harvest cultivation is to grow a stubble crop (white mustard, oilseed radish, oilseed rape or phacelia) if the precursor crop harvest was not too late and the soil has adequate moisture. In some locations, undersowing with a catch crop is a better solution. A dense catch crop will drown out volunteer cereals and weeds, and improve soil biology. It is beneficial to leave this crop in place over the winter (mulch) and thus forego winter ploughing. After a series of post-harvest cultivations, pre-winter ploughing (at a depth of 20–25 cm) is performed, leaving it in a sharp skid. This causes a loosening of the soil and an increase in soil porosity, which promotes greater water storage and a better effect of frost on the formation of the soil's tuberous structure.

In integrated conservation, a large role is attributed to the natural fertility of the soil and its high biological activity, so the number of ploughs should be limited – one every three years is sufficient. As for the other two years, ploughing should be replaced with tools that thoroughly scarify the soil without turning it over (heavy grubbers, subsoiler). A deeper soil scarifying with a subsoiler at 40–50 cm is sufficient once every 4–5 years.

Spring cultivation

The first possible early spring procedure should be harrowing or levelling (on compact soils). They reduce the evaporation of water from the soil and accelerate its heating. Before sowing, it is recommended to use a pneumatic sowing machine. Its string roller creates a compacted layer of soil just below the surface, which allows the seed to be placed at a similar depth and promotes even emergence. The use of the pneumatic sowing machine is economically justified (reduction of fuel and labour costs). Soil that is too moist should not be cultivated. On clumpy soil, complete two cultivation passes or use a cultivator. On light soils, spring cultivation should be reduced to a minimum due to the possibility of over-drying. On heavy soils, it is beneficial to use an active cultivator. In the case of cultivation with a cultivator (without an aggregate), it is recommended to equip the tractor with track eradicators or twin wheels to reduce soil compaction.

Properly performed cultivation of the soil is an important element of integrated protection of spring barley, reducing weed infestation. The possibility of obtaining optimal canopy architecture in such conditions, which positively influences plant development, promotes better resistance of barley to infestation by disease pathogens.

5.2. Sowing

Determining the optimum sowing date for winter barley can be difficult, as its effect on yield depends to a large extent on the course of the weather during the autumn period. The winter form of barley in the main growing areas should be sown in the second decade of September. The negative effect of early sowing is excessive vegetative growth of barley, conducive to the infestation of plants by the culprit of powdery mildew of real cereals and grasses, damage by the cereal crop, displacement during snowy winters and possibly infestation by the culprit of snow mold.

Spring brewing barley (more important in the country) requires an earlier date of sowing than the fodder type. This should be the end of March or the first 10 days of April (in case of a prolonged winter). Early sowing promotes a good fertilizer efficiency. Delaying the sowing date results in reduced grain yield, increased protein and husk content in the grain and deterioration in brewing quality, especially malt extractability. High quality treated seed should be used to obtain full and even emergence, which is crucial for proper plant growth and good canopy architecture. Seed material should be healthy, clean, with a high germination capacity.

Only treated seed material of at least the qualified category shall be used for sowing, and proof of purchase and seed labels must be kept for inspection.

The effect of sowing density on barley yield is related to plant competition for light, water and minerals. Plant density affects grain yield, but does not clearly affect its brewing quality. When planting density is too high, it intensifies competition between plants, increases their mutual shading and weakens resistance to lodging. Low sowing density results in an insufficient number of ears per unit area and promotes the spread of weeds. A large grain yield can be obtained with optimum sowing density, which depends on soil quality, the sowing date, and variety characteristics. A higher seed sowing rate is used in conditions where the plants don't go through so much tillering (poorer soil, delayed sowing) and with less propagating varieties. Brewing barley is sown somewhat more densely than feed barley to ensure limited tillering. Severe tillering weakens grain uniformity.

The ears of the main and first lateral shoots contain a more prolific and uniform grain than later grown lower shoots; therefore, it is better when the less bushy plants predominate strongly in the canopy. Sowing density has little effect on the protein content of barley grain. Plant stock density should be 370-400 germinating grains per 1 m^2, less frequent in better sites and denser in worse sites. A row spacing of 12-15 cm and sowing depth of 3 cm is recommended.

6. SUSTAINABLE FERTILISATION SYSTEM FOR BREWING BARLEY

The integrated fertilisation system is based on a nutrient balance, taking into account the uptake of nutrients by the plants and their input from natural and mineral fertilisers. This system is aimed not only at ensuring high fertilisation efficiency, which translates into better utilisation of the crop's yield potential, but also maintains soil fertility while at the same time ensuring the safety of the natural environment.

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).

Fertiliser management should be based on a decision support system that takes into account both classic fertiliser advice and operational advice consisting of so-called canopy management. The basis of fertiliser consultancy is an assessment of the basic physico-chemical properties of the soil, such as pH, phosphorus, potassium and magnesium abundance, and sometimes micronutrient content. Operational consultancy is based on soil and plant tests.

In barley cultivation, the fertilisation system is based on two objectives:

- regulating the soil pH response and the abundance of phosphorus, potassium and magnesium at an optimal level for barley growth and development;
- controlling plant growth and development to optimise yield by appropriate nitrogen fertilisation for brewery grain use.

When drawing up a fertilisation plan on the farm, you can use the recommendations of the District Chemical and Agricultural Stations, which not only perform soil testing for acidity and abundance of phosphorus, potassium, magnesium and mineral nitrogen in the soil profile in spring and autumn, but also make fertilisation recommendations for the crops.

6.1. Nutritional needs of brewing barley

Integrated barley production should take into account nutrients from all sources (soil, precursor crop, mineral fertilisers, and organic fertilisers). Due to its poorly developed root system and short growing period, barley has quite high nutrient requirements and requires balanced mineral fertilisation. The reaction to fertilisation depends to a large extent on the amount and distribution of rainfall. Generally, at a grain yield of 6 t/ha including straw, spring barley intakes about 120 kg N, 70 kg P_2O_5, 100 kg K_2O, 20 kg MgO, and 50 kg CaO.

The production of barley for brewing purposes requires a great care when applying mineral fertilisation, especially nitrogen fertilisation. The protein content of barley grown for brewing purposes should not exceed 11.5%. Hence the need to perform soil analysis in terms of mineral abundance in the soil.

6.2. Soil pH analysis

Out of all cereals, spring barley yield losses are greatest when the soil pH is not correct. **The optimum pH ranges from 5.7 on poorly loamy sands to 6.5 on heavy clays, with clay or silty soils producing the most reliable yields for this crop. Hence the need to perform soil analysis to determine its pH before the planned liming.** Liming is a necessary procedure for brewing barley, as low pH results in lower grain yields and excessively high protein content in the grain. Barley is very sensitive to excess free aluminium and manganese ions, which are released under acidic conditions and limit plant growth and development. Use carbonate lime on lighter soils and oxide lime on dense soils.

The negative reaction of barley to the acidic reaction of medium soils is so strong that under the influence of liming of soils with pH < 5.3 a yield increase of not less than 3.5 dt from ha is obtained. On such soils, liming is a prerequisite for good grain accuracy and low husk content.

On soils leached of magnesium, it is more beneficial to use calcium-magnesium fertilisers. With magnesium deficiencies in the soil, barley does not grow productive side shoots, it has a short ear and small grain.

6.3. Macro- and micronutrient fertilisation

Spring barley shows considerable sensitivity to phosphorus and potassium deficiency. Potassium deficiency in barley is manifested by straw limpness and susceptibility to lodging.

Macro and micro nutrient fertilisation in integrated barley production must be carried out at appropriate times and doses (depending on soil type and pH) following a nutrient balance.

In case of the integrated production, the average phosphorus doses applied under spring barley range from 55 to 70 kg P_2O_5/ha, and potassium doses from 65 to 85 kg K_2O/ha, depending on soil richness and expected grain yield. When phosphorus or potassium abundance is very low, obtaining high yields is very unlikely. In this case, the fertiliser doses should be increased by approximately 20–30 kg P_2O_5 or 30–40 K_2O/ha, which will not guarantee high yields, but will improve soil richness.

Phosphorous and potassium fertilisers should be applied entirely pre-sowing. The spring application in winter forms and the main application in spring barley is significantly less yielding. Barley has a root system that ages earlier than other cereals and therefore fertilizer components from late, surface application are not used by it.

Nitrogen fertilisation is a strong yield factor (affects the growth and yield of plants), but also affects grain quality parameters.

In the case of brewing barley, the nitrogen dose must not be as high as under fodder barley, due to the deterioration of the quality of the grain. Adequate protein content is associated not only with limited nitrogen fertilisation, but also with relatively high yields (nitrogen dilution effect), which in turn are obtained under conditions of proper fertilisation with phosphorus, potassium and magnesium, and sometimes also micro nutrients. N ratio: P : K for brewing barley should be 1 : 2. 3. Determining the optimum nitrogen dose is quite difficult and depends on a proper determination of the soil's nitrogen abundance, which is why the result of the mineral nitrogen test (N...) is very important. Higher abundance can be expected on dense soils (very good or good wheat complex) in a post-crop stand, especially where beets were grown. The optimal dose is the application of 25-30 kg N/ha.

In brewing barley cultivation of the spring type, nitrogen fertilisers should generally be applied pre-sowing, as late doses of N result in protein accumulation in the grain, especially its stock fractions. If a higher fertilisation dose is required (50-60 kg N), 1/3 to 1/4 of the dose may be applied until the barley tillering stage at the latest.

The winter brewing barley at a yield of 5.5-6 t of grain takes from the soil about 115-120 kg N (for each next ton of grain and straw about 22 kg N). Approximately 20 kg of nitrogen should be applied to winter brewing barley before sowing, and the rest in spring. The spring dose for the yield of 5.5 t per ha should be about 30 kg, and for the yield of 6.5 t per ha - about 50 kg N per ha. Due to the undesirable high protein content of the grain, only pre-sowing and single spring nitrogen fertilization is used in winter barley.

Barley is sensitive to micro nutrient deficiencies, most notably copper, manganese, and to a lesser extent molybdenum, boron and zinc. If brewing barley was pre-cropped with cereal crops, use a copper micro-fertiliser or a multi-nutrient cereal chelate micro-fertiliser. It has a positive effect on the weight of the grains in the ear, as well as on the technological quality of the grain.

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 brewing barley 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 plant protection (against weeds, pathogens, pests) with preference given to the use of non-chemical measures and methods that reduce the harmfulness of those organisms, 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;
- use of seed produced and assessed in accordance with seed legislation;
- the application of fertilisation and liming where appropriate;

- the use of hygiene measures (cleaning, disinfection) to prevent the occurrence and spread of harmful organisms;
- 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 their appropriate selection and 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 barley 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 about the scope of pesticide use for particular crops is placed on the product's label. The repository of plant protection products can be 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 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 barley 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

Protection against weed infestation is one of the key elements determining the cost-effectiveness of the production of brewing barley. Weed infestation occurs when weeds are present in quantities or masses which directly or indirectly cause economic losses, e.g. as a result of a significant reduction in the quality or quantity of yield, delay of harvesting, or reduction in the efficiency of machinery.

The harmfulness of weed infestation depends on the performed agrotechnical treatments, the biology and growth rate of weeds, as well as the potential for competing with the weeds of the cultivated plant itself. Environmental conditions, including soil type, availability of nutrients and hydrothermal conditions during the growing season, also have an impact on the harmfulness of weeding (Krawczyk et al. 2015).

In the development of the crop, the so-called ‘critical period of weed competition’ can be distinguished when the crop is most susceptible to weeds. In winter barley, this is usually the time interval from sowing to the end of the shrub phase (BBCH 29). On the other hand, in spring barley, it is the time interval from sowing to the initial stages of shooting in the blade (BBCH 30).

7.1.1. The most important weed species

Weed harmfulness depends on the habitat and thermo-humidity conditions, the biology and development rhythm of weeds and the vigour of the crop itself. The greatest losses are caused by weeds whose emergence can be observed in the initial stages of barley development, usually up to the tillering stage. This is the so-called ‘critical competition period’. At later development stages, barley's competitiveness against weeds increases significantly.

Among weeds, the greatest harm is displayed by species that are characterised by rapid development and high reproductive potential. The species composition of weeds and the number of weeds is mainly determined by agronomic activities.

In winter barley, monocotyledonous weed species, mainly common windgrass, are becoming increasingly problematic while locally, species such as slender meadow foxtail, rye brome or couch grass and, under simplified cultivation conditions, also barren brome may also be a problem. Among the dicotyledonous weeds in winter barley plantations, the most common species are field small-flowered crane’s-bill, common poppy, cornflower, field pansy, and wild buckwheat.

In spring barley, annual dicotyledonous weeds dominate the weed infestation structure. Some of the most common species include: lamb’s quarters, field violet, common chickweed, cornflower, common poppy, speedwells, Anthemideae weeds, wild buckwheat, shepherd's purse, field pennycress, catchweed, and many others. Locally, perennial species such as couch grass and field thistle are a problem.

In the integrated production of barley, production should be carried out using integrated plant protection and technological and biological advances.

7.1.2. Agronomic methods of weed management

Weeds are an inseparable part of farmland. The primary source of weed infestation are their diaspores (seeds, rhizomes, stolons, tubers, bulbs) present in the topsoil layer (Ruisi et al.). 2015). They are usually called 'soil seed bank', which constitutes the so-called 'potential weed infestation' (of soil). On the other hand, weed seedlings occurring in a crop are defined as: a current weed infestation.

An uncontrolled weed development usually results in the occurrence of undesirable vegetation in an amount or mass significantly limiting yield.

Various weed control methods should be implemented in the integrated production, taking into account preventive measures as well as direct weed destruction techniques (Dobrzański and Adamczewski 2013; Melander et al.). 2005). The main cause of weed infestation is the 'soil seed bank', which is why efforts should be made to reduce its abundance through various treatments, in all possible phases.

The strategy to reduce the size of the 'soil seed bank' of weeds should be initiated during the post-harvest tillage operations. These treatments should in particular target species of perennial weeds reproduced by underground stolons or rhizomes, such as: dandelions, thistles, field bindweed, sorrel. Subsequent cultivation treatments that stimulate weed diaspores to germinate while destroying weed seedlings significantly contribute to the reduction of the soil weed seed bank in the topsoil layer.

An important factor limiting weed growth is the uniform emergence of the crop at optimal planting density. Therefore, it is necessary to sow healthy, good-quality seed respecting the recommended agronomic deadlines and sowing density. Optimal planting reduces the risk of secondary weed growth.

In integrated production, treatments should be applied to limit both potential and current weed infestation. The most important activities include:

- appropriate selection of the site, taking into account crop rotation;
- weed control in the post-harvest cultivation of precursor crops based on mechanical or chemical treatments;
- the use of crop treatments as appropriate and in a way that does not lead to soil pulverisation and drying;
- the use of certified seed; adequate seed quality ensures rapid, even emergence and planned plant density when sowing is carried out under optimal conditions (sowing date, sowing depth, soil temperature and moisture, etc.);
- application of sustainable fertilisation;
- application of hygiene measures consisting of regular cleaning of machinery and equipment to prevent the spread of weeds.

7.1.3. Non-chemical methods of weed control

Prevention and agronomic methods

These include among others: selection of a suitable site for cultivation, appropriate crop rotation to prevent weed compensation, selection of varieties adapted to local soil and climatic conditions, careful soil cultivation, fertilisation based on analyses of the fertilisation needs of the crop and soil nutrient levels to achieve full crop vigour, appropriate sowing dates and plant density, careful maintenance during cultivation, and, as far as possible, preventing weeds from producing seeds.

Mechanical methods of weed control

Mechanical care of barley sowing based on harrowing or inter-row weeding can be performed when justified, and the prevailing conditions allow these treatments. Mechanical care, performed at the right time, is a beneficial treatment. In addition to destroying weeds and soil crust, it improves air-water relations (Spaeth et al. 2020, Peteinatos 2018, Rasmussen et al. 2009).

7.1.4. Chemical methods of weed control

Plant protection products, including herbicides authorised for use in European Union countries, are periodically reviewed in accordance with the latest studies and principles set out by the European Union. Strict requirements for the quality of the products, their toxicology and the impact on crops and the environment guarantee that the products recommended for cultivation pose no hazard to the user, the consumer, and the natural environment.

Herbicides and growth regulators shall be used in accordance with the current list of plant protection products recommended for Integrated Production (IP).

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-srodkowochrony-roslin-dla-integrowanej-produkcji.html.

The condition for effective action of herbicides is the correct selection of a suitable products and timely execution of the treatment. Only chemical herbicides listed in the following sources may be used in the certified integrated production of malting barley: '**List of herbicides recommended for the integrated production of agricultural plants**'. The list of plant protection products authorised for integrated production is available in the Online Pest Warning System at: (https://www.agrofagi.com.pl/133,wykaz-srodkow-ochrony-roslin-do-integrowanej-produkcji-w-uprawach-rolniczych).

In the case of the certified integrated production, cultivation may be supported by means defined as growth regulators, only by means covered by: **'List of growth regulators recommended for integrated production of agricultural plants'** at:

https://www.agrofagi.com.pl/133,wykaz-srodkow-ochrony-roslin-do-integrowanej-produkcji-w-uprawach-rolniczych.

Plant protection products included in the '**List of plant protection products for Integrated Production in agricultural crops'** were selected from the '**Register of plant protection products'**published on the website of the Ministry of Agriculture and Rural Development (MARD) https://www.gov.pl/web/rolnictwo/rejestr-rodkow-ochrony-roslin

based on their harmfulness to humans and warm-blooded animals, in accordance with labels, permits and decisions of the Ministry of Agriculture and Rural Development and the European Commission.

Information on the scope of use of chemical plant protection products for specific crops is provided on the labels of these products. The plant protection product search engine serves as a supporting tool for their selection. (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.

Plant rotation after herbicide application

Herbicides vary in duration of action and biodegradation in soil, which should be taken into account when planning subsequent crops. Each herbicide label contains a section: 'CROP ROTATION', which provides information on the possible cultivation of successive crops. Most herbicides do not pose a risk to follow-on crops, but some herbicides persist longer in the soil and may cause symptoms of phytotoxicity or stunting on following crops.

Weed resistance to herbicides and methods of limiting it

The occurrence of herbicide-resistant weed biotypes is becoming a serious problem, which is why proper monitoring is crucial in terms of preventing weed resistance to herbicides.

One of the factors contributing to the development of weed resistance to herbicides is improper weed control based only on a widespread use of herbicides, without taking into account other methods, in particular agronomic ones.

The risk of weed resistance to herbicides increases when herbicides with the same mechanism of action are used cyclically. In order to counteract the risk of weed resistance to herbicides, it is necessary, among other things, to use herbicides with a different mechanism of action or at least from different chemical groups alternately. For this purpose, classification according to the mechanism of action of the active substance based on the HRAC classification (*Herbicide Resistance Action Committee*) should be used when selecting the herbicide for the procedure. Individual mechanisms of action of the active substances of herbicides according to this classification are currently assigned numerical codes (formerly, letter codes were commonly used, which can still be found on the labels of plant protection products).

7.2. Reduction of disease vectors

7.2.1. The most important diseases

The winter and spring barley are exposed to diseases caused by pathogenic fungi and other pathogenic organisms and agents. The most common disease caused by pathogenic fungi in barley cultivation is barley net blotch. The occurrence of powdery mildew of cereals and grasses, barley rust, rhynchosporium secalis, ramularia, black leaf spot and fusarium ear blight can also be dangerous. Other pathogenic organisms, such as bacteria and phytoplasms, and agents — viruses — may also be present in the cultivation of this species. The occurrence of diseases caused by pathogenic organisms reduces the yield of barley on average by 5 to 10 %. The amount of losses may be locally greater and this is related to the weather conditions occurring during the growing season. In addition to the loss of yield due to the onset of diseases during the growing season, contamination of the grain with mycotoxins is dangerous for human and animal health. This is related to the presence on the ears of *Fusarium* fungi, which cause Fusarium ear blight and can produce toxic metabolites — mycotoxins.

In integrated production of malting barley, systematic field monitoring is mandatory from emergence to the beginning of ripening, at least once per week, in order to assess the occurrence of diseases (powdery mildew of cereals and grasses, net blotch of barley, barley rust, and barley leaf blotch). After heading, particular attention shall be paid to Fusarium head blight.

The current threat posed by pathogenic organisms is shown in Table 1. A threat to the amount of barley yield and its quality is posed by several diseases. Depending on the disease, they are caused by one or more pathogens. They can pose different risks and are difficult to diagnose, especially when there are two or more disease entities on a plantation at the same time. They are present in the cultivation of barley from the germination stage to the ripe stage of the grain.

Barley is exposed to numerous diseases caused by viral infections. Most viral cereal diseases in Poland do not cause severe crop losses and therefore do not pose a serious threat. However, the intensification of cultivation, the introduction of large-scale monocultures, close proximity of maize fields which are one of the main reservoirs of cereal viruses, as well as climate change which affect the biology and growth of the population of insect vectors of viruses foraging on young winter plants during long and warm autumn have increased the economic importance of several of them.

Currently, the barley yellow dwarf (BYDV) is the most dangerous viral disease found in all cereal-growing regions in the world. Based on the results of research conducted at the Institute of Plant Protection — National Research Institute [PL: IOR-PIB] in Poznań, it was found that this disease may occur on winter barley crops in all regions of Poland. Current data confirm that the barley yellow dwarf virus PAS (BYDV-PAS) is the main vector of the disease in Poland. In addition, research results indicate numerous cases of paralysis and an increase in the risk of winter barley cultivation by wheat dwarf virus (WDV). In previous years WDV infections have been found in the region of south and south-west Poland; it should now be assumed that the WDV, like BYDV-PAS, can occur on the above-mentioned crops throughout Poland. The latest results from 2023 indicate a new phytopathological threat to winter barley cultivation — the barley virus G (BVG). This newly detected virus in the region of Greater Poland and Silesia was present in mixed infections with BYDV and WDV. It is dangerous because the synergy effect of several viruses in mixed infections can lead to stronger symptoms of the disease and pose a serious threat to infected plants. Another viral disease of barley, somewhat forgotten in recent years, however, which should be mentioned here, is the barley yellow mosaic. This virosis is caused by two closely related species: barley yellow mosaic virus (BaYMV) and barley mild mosaic virus (BaMMV). The disease was first detected in Poland in 2008 when it caused severe losses in the cultivation of susceptible barley varieties in the region of Lower Silesia. As quickly as two years later, the presence of these viruses was confirmed in eight provinces of Poland, however, the cultivation of winter barley varieties that were resistant or tolerant resulted in inhibition of the effects of this dangerous virus.

Table 1. Economic importance of barley diseases in Poland

Disease	**Pathogen(s)**	**Potential threat**	
		Winter form	**Spring form**
Cereal ascochytosis	*Ascochyta graminicola*	++	+
Septoria leaf spot	*Helminthosporium* spp., *Helminthosporium sativum*	+	+
Sooty mould black mould on wheat ears	*Cladosporium herbarum*, *Alternaria alternata*, *Alternaria* spp.	+	+
Fusarium ear blight	*Fusarium avenaceum*, *F. graminearum*, *F. culmorum*, *Microdochium nivale*	+++	++
Fusarium stem base and root rot	*Fusarium avenaceum*, *F. graminearum*, *F. culmorum*, *Fusarium* spp.	++	+
Loose smut of barley	*Ustilago nuda*	+++	++
Covered smut of barley	*Ustilago hordei*	++	+
Cereal stem breakage	*Ocumlimacula acuformis*, *O. yallundae*	++	+
Powdery mildew of cereals and grass	*Blumeria graminis*	+++	+++
Barley leaf stripe disease	*Pyrenophora graminea*	++	++
Barley net blotch	*Pyrenophora teres*	++	+++
Barley rust	*Puccinia hordei*	++	++
Stem rust of cereals and grasses	*Puccinia graminis*	+	+
Yellow rust	*Puccinia striiformis*	+	+
Cereal rhynchosporiosis	*Rhynchosporium secalis*	+++	++
Ergot of cereals and grasses	*Sphacelia segetum*	+	+
Head blight and root rot	*Bipolaris sorokiniana*	+	+
Seedling blight	*Fusarium avenaceum*, *F. graminearum*, *F. culmorum*, *Pythium* spp., *Rhizoctonia* spp., *Alternaria alternata*, *Alternaria* spp.	++	++
Barley yellow dwarf	*Barley yellow dwarf virus-PAS* (BYDV-PAS), *Barley yellow dwarf virus-MAV* (BYDV-MAV), *Barley yellow dwarf virus-PAV* (BYDV-PAV)	+	–

Wheat dwarfism on barley	*Wheat dwarf virus* (WDV)	+	–
Barley yellow virus G (BVG)	*Barley virus G* (BVG)	no data	–
Barley yellow mosaic	*Barley yellow mosaic virus* (BaYMV), *Barley mild mosaic virus* (BaMWV)	+ in the case of sowing sensitive varieties	–

+ disease of local importance; ++ important disease; +++ very important disease; — disease without significance

7.2.2. Methods of monitoring the causes of diseases

Weather conditions, especially humidity conditions and the amount and distribution of rainfall during the growing season, temperature and sunshine play a significant role in the severity and timing of disease outbreaks. In the integrated production, it is advisable to know the sources of infection and conditions are conducive to the occurrence of diseases. Thanks to this, it is possible to determine the problematic disease with high accuracy and determine its severity in order to apply a possible threshold of harmfulness. This information also makes it possible to reduce the prevalence of certain diseases in subsequent years through actions, e.g. agrotechnical, sowing of varieties resistant to pathogen infestation. Table 2 gives indicative conditions under which the main mushrooms causing barley diseases may develop (Korbas et al. 2015, 2016, Kryczyński and Weber 2011).

Table 2. Indicative conditions favouring the development of selected barley pathogens

Disease	Sources of infection	Favourable conditions for development	
		temperature [°C]	**soil and air humidity**
Cereal ascochytosis	infested plants — volunteer seeds, crop residues	12–25	high relative air humidity
Septoria leaf spot	self-sown seeds, post-harvesting residues	15–20	high relative air humidity
Sooty mould black mould on wheat ears	post-harvesting residues, conidial spores carried by rain and wind	15–25	high relative air humidity
Fusarium ear blight	post-harvesting residues, spores spread with rain drops	15–25	heat, high relative air humidity
Fusarium stem base and root rot	crop residues, infested grains, spores spread with raindrops	5–25	high relative air and soil humidity or desiccated soil
Loose smut of barley	infected seeds	16–22	–
Covered smut of barley	contaminated seeds	14–25	–
Cereal stem breakage	post-harvesting residues, conidial spores, ascospores	5–15	high air and soil humidity
Powdery mildew of cereals and grass	conidial spores, ascospores	5–22	50–100 % of relative air humidity
Barley leaf stripe disease	infected grains	15–20	–
Barley net blotch	infected grains, volunteer seeds, crop residues	15–25	high relative air humidity
Barley rust	infested volunteer seeds	5–22	high humidity
Stem rust of cereals and grasses	aeciospores arising on an intermediate host	approximately 20	high relative air humidity

	(barberry and mahonia)		
Yellow rust	urediniospores of volunteer and winter cereals	10–15, new pathotypes 10–28	high humidity, new pathotypes - dry
Cereal rhynchosporiosis	infested grains, conidial spores	5–20	high humidity
Ergot of cereals and grasses	sclerotia in the soil or in the seed, honey dew during flowering, presence of insects	18–25	dry and warm
Head blight and root rot	post-harvesting residues	2–25	high humidity, moist soil
Seedling blight	soil, seeds	5–25	high
Barley yellow dwarf	infected self-sown seeds, infected wild grasses, presence of aphids	10–25	moderate relative humidity
Wheat dwarf on barley	infected self-sown seeds, infected wild grasses, presence of leafhoppers	10–25	moderate relative humidity
Barley yellow virus G (BVG)	infected self-sown seeds, infected wild grasses, presence of aphids	10–25	moderate relative humidity
Barley yellow mosaic	presence of an infectious vector — *Polymyxa graminis* in the substrate	do 17	high humidity, moist soil

Korbas et al. (2015, 2016), Kryczyński and Weber (2011)

In addition to knowing the conditions conducive to the occurrence of a given disease, it is also important to define it correctly. Table 3 contains information that will facilitate the diagnosis of barley diseases present during the barley growth period. Thanks to this, it is possible to determine with high accuracy with which disease the problem is and determine the severity of its occurrence. This information should be used to clarify the date of control when a chemical method is required for the application of the threshold of harmfulness existing for a specific disease.

Table 3. Main diagnostic features of barley diseases

Disease	**Diagnostic features**
Cereal ascochytosis	Oval spots surrounded by a brown border, the inside of the spots white, parchment-like, with black globular fruiting bodies on the surface of the spots. Symptoms occur on leaves, leaf sheaths and ears.
Septoria leaf spot	Symptoms on the leaf sheaths occur in the form of dark brown, necrotic lesions. There are oval, elongated light or dark brown spots on the leaf blades and sheaths. The infected ears blacken, and the grain is wrinkled.
Sooty mould black mould on wheat ears	A characteristic black soot-like coating appears on mature ears or prematurely dried plant parts, covering all or part of the ear. The fungi behind the disease cause the ears and canopy to change colour from golden yellow to grey-brown.
Fusarium ear blight	Lesions are observed on ears and grains. Yellow, partial or complete discolouration of the ears indicates an infestation by the disease pathogen. At high humidity, the infected ears become covered with white or pink coating. Orange spore clusters (sporodochia) are visible on the ears. Grain infested by certain fungi of the genus *Fusarium* may contain toxins highly poisonous for humans and animals.
Fusarium stem base and root rot	Fungal infestation affects the roots and the base of the stem. They can take the form of russet or brown streaks, dashes and patches of irregular shape. Leaf sheaths change from green to brown. Sometimes the browning of the whole base of the stem and roots can be observed. The final stage of the disease is the complete, premature death of infested shoots and the so-called

	bleaching of ears.
Loose smut of barley	The ears of infested plants emerge a little earlier than the ears of healthy plants. The dark-brown spore clusters of the loose smut of barley that cover the whole ear initially have a delicate greyish-white cover in the form of a membrane which is soon destroyed, and the mass of dark-brown spores (teliospores) is dispersed in the wind leaving only ears with spikelets.
Covered smut of barley	The ears of the plants remain in the leaf sheaths or emerge from them only partially. Barley ears with altered grains do not change shape and are covered with a thin, silvery membrane, which is the residue of husks and chaff. The brown mass of spores is initially soft, then hardens and disintegrates into lumps. The leaves and stems of infested plants stay green for a long time.
Cereal stem breakage	Symptoms can be detected as early as in autumn or early spring; they take the form of small, slightly elongated brown spots on the surface of leaf sheaths. In the central part of the blotches, black ‘patches’ are formed. In case of a severe infestation, the entire base of the barley stalk decays. In the infested area, the stem is brittle and breaks easily. Heavily infested stems have white, dead ears and break off easily when they are pulled out of the ground. If the disease is severe, grain yield losses can be around 30 %.
Powdery mildew of cereals and grass	Clusters of white coating, or ectomycelium, appear on the green parts of the plants — leaves, leaf sheaths, and later on stems and chaffs. Initially, these clusters are one to several mm in diameter and at this stage, they are formed by loose, white mycelium, with stems and conidial spores. Within the older, compact coating, dark brown fruiting bodies resembling black spots are formed. In Poland, losses caused by powdery mildew amount to the average of about 8 % of the grain yield; sometimes they are much higher and exceed 40 %. The immunological response is the appearance of brown patches on the surface of which mycelium can be seen. Necrotic patches may also be visible – a hypersensitivity reaction to *Blumeria graminis*.
Barley leaf stripe disease	During the stem elongation phase, the leaves initially show yellow and later brown long streaks between the nerves. A brown coating of conidial spores of the fungus may appear on the patches. In places of discolouration, the leaves split along the stripes, giving the leaf a shredded appearance. The leaves gradually die before or at the time of earing. Plants are lower and do not go through the earing stage or produce tailings or barren ears.
Barley net blotch	Symptoms occur in all stages of plant development. On the leaves, there are initially small brown spots that consist of transverse and longitudinal brown necroses, forming a ‘net’ pattern, and may occur simultaneously in several places on the leaf (typical symptoms). On these patches, gradually, we observe chlorosis and yellowing of the leaf blade; heavily infested leaves die off. Sometimes you can also observe brown or dark brown patches of irregular shape with a narrow yellow border. They can be patches in the form of spots or streaks (atypical symptoms). The type of symptoms depends on the strain of the fungus and the reaction of the variety. Symptoms in the form of brown, irregular spots are also observed on the leaf sheaths, stems, ears, awns and chaff. The kernels may also be infected and acquire a darker colour.
Barley rust	Uredinia, or clusters of urediniospores (propagule spores), are mainly visible on the upper side of the leaves under the skin, in the form of orange or rusty-brown pads. Towards the end of the growing season, black clusters of teliospores (autumn spores) are visible on the underside of the leaves.
Stem rust of cereals and grasses	The infestation mainly affects the stems and leaf sheaths of cereals. The spore clusters of this rust initially develop under the skin. Over time, the skin breaks and its jagged edges are clearly visible among the mature, dark-coloured urediniospores (clusters of summer spores). At a slightly later stage, the formation of black clusters of teliospores (autumn spores) is observed in the infested areas.
Yellow rust	The symptoms are very characteristic and most visible in May or June. Uredinia (clusters of summer spores) of yellow-orange colour of elongated shape and slightly erected under the skin and are arranged linearly, between the veins. Rows of uredinia form yellow stripes a few millimetres long.
Cereal rhynchosporiosis	Symptoms of the disease are visible from the beginning of the shooting stage on the leaves and leaf sheaths in the form of oval or lenticular light green spots, which turn straw-coloured or light brown over time. There is a distinct brown border around the stain, sometimes clearly separated from the healthy part. When heavily infested, the spots merge together and form an irregular necrosis. When the spots are present at the base of the leaf, the leaf dries out.
Ergot of cereals and grasses	During the period of flowering of cereals, droplets of yellowish thick secretion appear on infected ears. Soon afterwards, sclerotia — violet-black ergot cones — develop in the individual spikelets instead of seeds. They are elongated, arched, hard, and also brittle.
Head blight and root rot	Dead, russet-brown roots, stalled growth, ears become whitish.
Damping off	Pre-emergence blight manifests itself through a lack of plant emergence — pathogenic fungi infect the sprouts and embryonic roots, which turn brown which then results in the young plant

	dying. In the case of post-emergence blight, plants germinate and appear above the soil surface, but their growth is stalled and they are poorly formed. As they become severely infested, they turn yellowish and die over time.
Barley yellow dwarf	The growth of the infected plants is stalled and their leaves become discoloured. Barley leaves are discoloured to intensely yellow, and dwarfing is also observed. Colour changes are initially formed on the tops of the leaves, and then cover the entire surface of the leaf blade. The leaves become brittle and stiff and the increase in tillering leads to a change in the appearance of the plant as it becomes bushy. Infested plants can be seen in the field mostly stunted in growth, clustered in focal points, although scattered infestations also occur. The development stage of the plant at the time of infection is very important with respect to symptoms; the earlier it is, the stronger the symptoms, and the affected plants have severely reduced spikelet stalks. Factors such as virus species, temperature, and even light intensity, as well as varietal response, also influence the form of symptoms. Despite some variation in the response among barley varieties, no satisfactory level of resistance/tolerance to yellow dwarf disease has yet been achieved. Infected plants are more susceptible to secondary infections by fungi.
Wheat dwarf on barley	Similarly, as with other viral pathogens, symptoms of barley infestation by WDV usually appear in early spring. The main and dominant symptom of the disease is dwarfism caused by shortening of internodes and limited development of the roots of infected plants. In addition, during observation of infected plants, it is also possible to find wrinkling and twisting of young leaves on which mosaic sometimes appears, and in the final stages of the disease — also yellowing and browning of the whole blades. Infections of plants in the early stages of their development (BBCH 11-12) lead to the rapid development of the disease, necrotisation and premature death of whole plants. Despite the rather characteristic symptoms, WDV infestation of barley may be mistaken for symptoms of BYDV. The harmfulness of the disease is mainly caused by the reduction of ears and the formation of barren ears in infested plants. Losses of crops may reach 80 or even 100 %. Until recently, the WDV on barley was infrequent in Poland and the disease did not pose a serious threat to crops. Infected and dying individual plants were mainly found at the field edges or along technological access paths. However, in recent years, this disease has become increasingly significant. The infested plants were a large group covering entire fields which, in extreme cases, even led to re-sowing of such crops. In addition, an increase in the extent of the viral disease is being observed. Currently, it should be assumed that BYDV and WDV viruses can occur on winter barley crops throughout Poland. Infected plants are more susceptible to secondary infections by fungi.
Barley yellow virus G (BVG)	The virus causes yellow discolouration of the tops and edges of the leaves. Due to the widespread occurrence of BVG in infections combined with other cereal viral diseases (e.g. BYDV and WDV), its direct harmfulness cannot be estimated. However, it should be stressed that the synergy effect of several viruses in mixed infections can lead to stronger symptoms of the disease and pose a serious threat to infected plants. Infected plants are more susceptible to secondary infections by fungi.
Barley yellow mosaic	Symptoms appear in early spring at low temperatures only, they disappear above 15 °C. They are less specific and occur in the form of tiny spots, streaks that, by expanding, lead to yellowing of the leaves and even to their necrotisation. The growth and development of infected plants and their roots may also be stunned. Infected plants in a weaker condition can usually be found in fields in natural recesses of the terrain and along water courses, but the disease can also be asymptomatic. Infected plants are more susceptible to secondary infections by fungi.

Korbas et al. (2015, 2016), Kryczyński and Weber (2011)

In the absence of direct chemical control of viruses by the use of plant protection products, preventive measures are the only way to reduce the diseases they cause. That is why it is so important to monitor barley crops from the very beginning of their vegetation for the presence of insect vectors of viral diseases, i.e. different species of aphids and leafhoppers. In such situations, modern tools such as the pest signalling platform, available on the IOR-PIB website at https://www.agrofagi.com.pl., are helpful.

Alerts on current threats from various crop pathogens, such as the results of research on the infectiousness of the main vectors of cereal viroses, or data on the incidence of specific viruses on crops can be found there. In addition, current analysis results can be found there, such as those obtained through the network of Johnson aspirators recording the flights and catching insects from the air, including aphids, which are very important in the context of viral infections. Signalling aphid flights is very helpful as the cameras catch insects a few days in advance before they appear in the fields and populate young plants. Another alternative method, used directly for local purposes in specific fields, may be to use insect traps in the form of yellow vessels filled with water. Regardless of the observation of the appearance of insect vectors, field inspection should be carried out and particular attention should be paid to all kinds of anomalies associated with the normal growth and size of plants in a given crop, and in the event of suspicious symptoms, a laboratory analysis should be commissioned.

7.2.3. Agronomic methods of disease vectors control

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. The following agrotechnical practices are of particular importance, among others:

- appropriate crop rotation and site selection,
- proper preparation of the soil for sowing and timely sowing;
- rational feeding of plants,
- compliance with the rules of proper fertilisation, timing and density of sowing.

In order to reduce the incidence of crop rotation-related diseases, a break in cultivation should be observed. If the interval between barley crops is too short, an increased incidence of diseases can be expected, particularly those caused by fungi of the genus Fusarium. The right harvest date also influences the presence of fungi in the crop, on the straw or stubble. The measures mentioned above (Table 4) that are implemented in the agronomic method make it possible to greatly reduce the risk of diseases caused by fungi. It is advisable to use as many elements as possible that reduce the occurrence of diseases. Barley which grows and develops in optimal conditions makes it possible to obtain a satisfactory yield, both in terms of quality and quantity.

Table 4. Agronomic methods for reducing the most important barley diseases

Disease	Key agronomic limitation measures
Cereal ascochytosis	appropriate crop rotation; destruction of crop residues
Septoria leaf spot	appropriate crop rotation; destruction of crop residues
Sooty mould black mould on wheat ears	appropriate crop rotation; destruction of crop residues; spatial isolation - the distance between spring and winter plantations; optimal fertilisation with reduced N dose; optimal harvesting date
Fusarium ear blight	appropriate crop rotation, careful ploughing in of crop residues, destruction of volunteer seeds and optimisation of nitrogen fertilisation
Fusarium stem base and root rot	appropriate crop rotation, careful ploughing in of crop residues, destruction of volunteer seeds
Loose smut of barley	use certified grains for sowing.
Covered smut of barley	use certified grains for sowing.

Cereal stem breakage	crop rotation, early and accurate ploughing, destruction of volunteer seeds and optimisation of nitrogen fertilisation
Powdery mildew of cereals and grass	ploughing up stubble, destroying self-sown seeds, appropriate sowing density, balanced fertilisation (avoiding excess nitrogen), avoiding sowing spring barleys in the vicinity of winter barleys.
Barley leaf stripe disease	sowing healthy seed, delayed sowing date
Barley net blotch	sowing healthy seeds, destroying crop residues and volunteer seeds, appropriate crop rotation, and avoiding sowing spring barleys in the vicinity of winter barleys.
Barley rust	ploughing and deep ploughing, destruction of volunteer seeds, avoiding sowing spring barley in the vicinity of winter barley
Stem rust of cereals and grasses	ploughing in of crop residues, destruction of intermediate hosts (barberry and mahonia), sowing of early-maturing varieties
Yellow rust	carrying out ploughing and deep ploughing, destruction of self-sown seeds, avoiding sowing spring barleys in the vicinity of winter barleys
Cereal rhynchosporiosis	appropriate crop rotation, careful ploughing in of crop residues, destruction of volunteer seeds, balanced fertilisation, and avoiding sowing spring barleys next to winter barleys
Ergot of cereals and grasses	sowing thoroughly cleaned grain, clearing the grass before formation of sclerotia, ploughing post-harvesting residues
Head blight and root rot	suitable crop rotation, a 3–4 year break in cereal cultivation in the same field is recommended, early and accurate harvesting
Seedling blight	crop rotation, optimal date of sowing; the correct depth and standard of sowing; good soil structure, balanced fertilisation
Barley yellow dwarf	crop rotation, delay of sowing time, balanced fertilisation (avoiding excessive nitrogen), destruction of crop residues and self-sowing as virus reservoirs, avoiding the neighbourhood of maize monocultures
Wheat dwarf on barley	crop rotation, delay of sowing, balanced fertilisation (avoiding excess nitrogen), destruction of crop residues and self-sown seeds as virus reservoirs
Barley yellow virus G (BVG)	crop rotation, delay of sowing time, balanced fertilisation (avoiding excessive nitrogen), destruction of crop residues and self-sowing as virus reservoirs, avoiding the neighbourhood of maize monocultures
Barley yellow mosaic	sowing of tolerant/resistant varieties, creating optimal conditions for the development of barley

It is very important to select suitable varieties, as resistant or tolerant as possible, as part of preventive measures for the discussed diseases of barley viral diseases. The list of recommended varieties (LVR) drawn up by COBORU contains the varieties recommended for each region. In the characteristics of these varieties, information about the reaction of plants to certain cereal viruses can also be found. In addition, the following measures are also very important: avoiding premature sowing of winter barley, using spatial isolation of barley crops from other cereal crops and maize, using crop rotation, using balanced fertilisation, removing diseased plants, including weeds, and thorough grinding and deep ploughing of crop residues and volunteer seeds, in order to eliminate any potential virus reservoirs. When describing the importance of agronomic preventive measures, it is important to stress their particular relevance for protecting crops against barley yellow mosaic. Therefore, it is crucial to correctly diagnose the disease, to determine the sites of this disease and to be particularly careful and cautious in agrotechnical procedures so as not to further transfer the soil particles together with the infective vector to the new virus-free areas. In this way, the spread of the disease will be prevented.

7.2.4. Chemical methods of disease vectors control

At present, the application of chemical methods in barley cultivation is possible through seed dressing and foliar spraying during the growing season. **For sowing in the**

integrated production of brewing barley, the use of certified and treated seed is required in accordance with the ESTA standard or an equivalent standard.

Plant protection products should be used in accordance with the current list of products recommended for growing barley within the integrated production system (IP). Messages from the Online Pest Warning System (www.agrofagi.com.pl) may be helpful. Use instructions on the label should be read before application.

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 repository of plant protection products can be 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 on the Online Pest Signalling Platform at: https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.html.

The sowing of treated seed is the only effective method for controlling the pathogens responsible for seedling blight, covered smut, loose smut, and barley stripe. Seed dressing protects the germinating kernels from infection by fungi and pathogenic organisms that may be on the surface and inside the kernel as well as living in the soil.

The use of fungicide treatments during the growing season depends on the severity of the disease. During years with less pressure from disease-causing fungi, it is sufficient to sow the treated seed and carry out one spray treatment with a suitable fungicide, while during those years when weather conditions are favourable for diseases, two treatments are advisable. There may be exceptional situations where conditions favour the epidemic incidence of a given disease. Then consideration should be given to performing an additional procedure.

In some years, under warm autumn conditions, winter barley plants may become infected by pathogenic fungi already in the autumn. Sometimes the severity of infestation on densely planted fields at more fertile sites requires the use of fungicides still in autumn. In general, the first treatment in barley can be carried out from the end of the tillering stage (BBCH 29) to the stem elongation stage – first and second node detectable (BBCH 30–32). Of course, if symptoms appear earlier and with high intensity, the treatment should be advanced and carried out at the beginning of the tillering stage. The treatment performed at the end of the propagation phase / the beginning of shooting in the blade reduces the occurrence of diseases of the base of the blade, which are less important in the spring form of barley and diseases on the leaves. Carrying out this treatment helps prevent the occurrence of leaf disease symptoms such as: net blotch of barley, barley rust, barley leaf spot, and powdery mildew of cereals and grasses. This treatment, when there is no risk of stem breakage and fusarium head blight and root rot, can be delayed until the disease has occurred at such an intensity that the economic harmfulness threshold is surpassed. Depending on the severity of the diseases occurring in the flag leaf phase, a treatment may be performed to protect the highest leaves.

Another important treatment performed during the earing phase is mainly aimed at combating fusarium ear blight pathogens.

Harmfulness thresholds

Proper field inspections are the basis for deciding which treatments should be carried out based on damage thresholds (if they have been set for the disease in question). Depending on the development stage of the crop and the disease, a plantation health analysis should be carried out based on the following guidelines.

For diseases occurring on the leaves in the early stages of development (tillering — BBCH scale 21–29), 100 to 150 plants (depending on the size of the field) taken from several randomly selected sites should be analysed for the first symptoms of the disease.

At later development stages (from the stem elongation stage — BBCH scale 30–39 to earing — BBCH scale 59), the analysis should be carried out by observing 100 to 150 blades, and when disease symptoms are present on the flag leaf, sub-flag leaf or ear, 100 to 150 leaves are examine and the result is given as a percentage of the infected area of the analysed parts of the plant.

In case of diseases of the stem base (stem breakage, fusarium head blight and root rot) the basis of observation is sampling (30 or more stems) and analysing them for the presence of the pathogen. In order to determine the percentage of infested stems and roots, the outer surfaces of the sheaths of the lowest leaves and roots are inspected.

As for fusarium ear blight, the damage threshold is defined as the first symptoms of the presence of the disease pathogens or a positive result of the paper bag test for the presence of the pathogen. It consists in taking a few dozen ears from different parts of the field which are then spread out on pre-moistened newspaper, then which is folded and placed in a paper bag. All of this is then placed in a plastic bag and then left in a dark place, such as a drawer. If there is more than one field, it is best to describe each bag, indicating where the sample was taken and the date and time. The test is best assessed 96 hours after its initiation, checking if the paper is still damp after 48–72 hours, and if it is dry it should be moistened to maintain the moisture content, which is conducive to fungal growth. Several such tests can be performed during earing, especially when it is warm and humid.

Decision support systems

For more information, see: www.iorpib.poznan.pl, www.iung.pulawy.pl, www.ihar.edu.pl, www.imgw.pl, www.minrol.gov.pl.

In integrated production, treatment decisions should be based on available damage thresholds (Table 5).

When several disease pathogens are present at the same time, but not exceeding the damage threshold, it makes sense to add these specific threshold values. If the sum of pathogens present reaches the threshold values for one of the pathogens, a decision must be made to perform a treatment using a fungicide. As per a well-known principle, it is better to do something sooner than later.

Table 5. Indicative economic damage thresholds for major barley diseases

Disease	Observation date	Economic damage threshold
Fragility of the stalks of cereals and grasses	from the beginning of the stem elongation phase to the phase of the first node	20-30% of stems with initial infestation symptoms
Powdery mildew of cereals and grass	during the tillering stage	25-35% of plants with first symptoms of infestation (isolated white clusters of fungal structures)
	during the stem elongation stage	10 % of stems with infestation symptoms
Net blotch	during the tillering stage	15–20 % of leaf area with disease symptoms
	during the stem elongation stage	15–20 % of leaf area with disease symptoms
Barley rust	during the tillering stage	10–15% of leaves with initial infestation symptoms
	during the stem elongation stage	10 % of stems with infestation symptoms
Cereal rhynchosporiosis	during the tillering stage	15–20 % of leaf area with disease symptoms
	during the stem elongation stage	15–20 % of leaf area with disease symptoms

7.3. Reduction of losses caused by pests

7.3.1. Most important pests

In Poland, the most important pests that occur on cereal plantations are aphids, cereal leaf beetles and gall midges. Over the past few years local, sometimes in huge numbers, occurrences have been observed of some other pests, such as Bishop’s Mitre, tortoise bug, ground beetle, cereal chafer, leaf miner, frit fly, bean seed fly, and soil pests, mainly turnip moths, grubs and wireworms. Cereals may also be damaged by slugs, rodents, thrips, wheat stem fly, saddle gall midge, nematodes, birds and game animals, as well as tortrix caterpillars (Table 6) (Mrówczyński et al. 2017, Tratwal et al. 2017; Hołubowicz-Kliza et al. 2018, Grzebisz et al. 2021). Pests can cause damage to both above- and underground parts of plants (Tables 7 and 8).

It is extremely important to carry out systematic monitoring of the field in the integrated production of malting barley from emergence to the beginning of maturation at least once a week for the occurrence of pests (aphids, cereal leaf beetles and gall midges) (direct plant inspection, yellow vessels, etc.).

Table 6. Current and projected importance of barley pests in Poland

Pest	Current	Forecast
Wireworms	+(+)	+++
Bishop's Mitre	++	+++
Bibionidae (march flies)	+	++
Ground beetle	++(+)	+++
Leaf miners	+(+)	++
Aphids	++(+)	+++
Cereal chafer	+	++
Chlorops ringens	+	++
Grubs	++	+++
Frit fly	++	+++
Gall midges	++	+++
Cutworms	++	+++
Leafhopper	+(+)	++
Cereal leaf beetle	++(+)	+++
Root flies	+(+)	++
Thrips	+(+)	++
Leafroller moths	+	++
Wheat stem-sawfly	+	++
Tortoise bug	++	+++
Rodents	(+)	+
Snails	+	++
Game and birds	+	+(+)

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

Table 7. Damage to the underground parts of barley plants caused by pests

Pest	Damage description
Wireworms	Damage to the root system — bitten off lateral roots and traces of gnawing of the main root.
Rodents	Damage to the root system — biting plants while digging burrows underneath them. Leaf and stem damage is also observed — especially in the early stages of cereal development.
Bibionidae (march flies)	Damage to the root system — bitten off lateral roots and traces of gnawing of the main root.
Ground beetle	Damage to germinating plants (larvae), to a lesser extent to kernels (imago).
Nematodes	Stunted plants, growing very slowly, with leaves bending and wilting. Distortions and globules — nematode cysts — can be observed on the roots.
Grubs	Damage to the root system — bitten lateral roots and the main root.
Cutworms	Plants are bitten near the root neck, causing them to be severed from the roots. Some of these are pulled into holes previously made by the caterpillars in the soil. The caterpillars at the youngest and oldest growth stages can feed on aboveground plant parts.
Turnip maggot Wheat-bulb fly	Damage to germinating grains, roots and tissues of young plants.

Table 8. Damage to the above-ground parts of barley plants caused by pests

Pest	Damage description
Bishop's Mitre	Foraging on leaves and stems — yellowing and drying of leaves. Foraging on kernels — bleaching of ears, reduction of kernels in the ear, underdevelopment of kernels, and deterioration of kernel quality.
Leaf miners	Eating out the parenchyma between the upper and lower leaf skin, usually along the veins — reducing the assimilative surface (usually flag and sub-flag leaves).
Aphids	Direct damage (sap sucking) — loss of turgor, twisting and wilting of leaves. Indirect damage (transmission of viruses, mainly BYDV) — leaf discolouration, tillering, dwarfism, absence or low number of spikelets. In addition, secondary infestations by the disease pathogens.
Cereal chafer	Damage to flowers and forming grains leading to the bleaching of parts of the ear (imago), and damage to the root system (larvae).
Chlorops ringens	Damage to young seedlings and growth cones leads to stunted growth, shoot distortion, excessive tillering, yellowing of leaves, shortened ears or dying of entire plants.
Frit fly	Damage to the base of the shoot can result in whole plants dying or excessive tillering with few (or no) spikelets (characteristic yellowing heart leaf).
Gall midges	Weakening and shortening of the stem, abnormal development of ears and grains, reduced quality and germination of grains.
Leafhoppers	Due to sap sucking — weakening of growth, wilting and drying of plant parts. Like aphids, leafhoppers can act as vectors of viruses (including WDV).
Cereal leaf beetle	Eating the tissue along the leaf veins — reduction in assimilative surface area and photosynthesis, secondary infestation by disease pathogens.
Snails	After emergence, the seedlings are either entirely eaten or nibbled until completely cut off by slugs, just above the soil surface.
Thrips	Leaf deformation, failure of ears to emerge from the leaf sheaths, bleaching of the tops of the ears, deformation of the grains and deterioration in grain quality.
Game and birds	Eating of seeds or germinating plants during their emergence (birds) and gnawing of plants at later stages of development (game).
Leafroller moths	The greatest losses occur when caterpillars fodder on the ears; they usually destroy 3-4 kernels.
Wheat stem-sawfly	Larvae foraging causes underdevelopment of the ears or inadequate grain filling. Plants damaged at the base of the stem are easily broken.
Tortoise bug	Foraging on leaves and stems — yellowing and drying of leaves. Foraging on kernels — bleaching of ears, reduction of kernels in the ear, underdevelopment of kernels, and deterioration of kernel quality.

The main idea of integrated pest management is to use all available pest control methods while minimising the use of insecticides. It is a programme to manage pests in such a way as to keep their population below the threshold of economic damage. In integrated cereal protection, non-chemical methods are used first, and only when the crop is threatened beyond the damage threshold is insecticide protection applied. Prevention is very important, i.e. preventive action with all available non-chemical methods that reduce the number and development of pests.

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 m2 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 observations should be recorded (Tratwal et al. 2017).

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

Integrated crop production requires farmers to possess substantial knowledge and experience, ranging from pest identification, through understanding its development stages and habitats, to methods of its control and eradication. 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 protection is systems supporting the adoption of decisions in plant protection. These systems are helpful in determining the optimal timelines 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 the 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 making decisions about the optimal treatment dates. For each pest species, basic information is provided on its morphology, biology and methods of field observation, as well as the value of the thresholds for economic harmfulness. Thresholds of economic harmfulness are the fundamental basis for rational protection. In the case of barley, detailed economic threshold levels have been established for certain pest species. The principles and deadlines for their observation and the harmfulness thresholds are set out in Table 9.

Table 9. Observation dates and economic damage thresholds for barley pests

Pest	Observation date	Damage threshold
Wireworms	before sowing	10–20 larvae per 1 m^2
Ground beetle	autumn — emergence until vegetation cessation	1-2 larvae or 4 freshly damaged plants per 1 m^2
	spring — beginning of the growing season	3-5 larvae or 8-10 freshly damaged plants per 1 m^2
Aphids	earing or immediately after earing	5 aphids per 1 ear
Cereal chafer	flowering and grain development	3–5 beetles per 1 m^2 or 5 grubs per 1 m^2
Wheat yellow blossom midge	earing	5–10 insects per 1 ear
Wheat midge	earing	8 larvae per 1 ear
Saddle gall midge	flag leaf fall	15 eggs per 1 stem
Cutworms	before sowing	6–8 caterpillars per 1 m^2
Cereal leaf beetle	flag leaf fall	1–1.5 larvae per blade
Root flies	in the spring	10 damaged plants per 30 tested or 80 larvae per 1 m^2
Thrips	stem elongation for full flowering	10 larvae per blade, 5–10 adult insects or larvae per 1 ear
Tortoise bug	Spring growth and tillering	2–3 adults per 1 m^2
	grain development, late milk stage	2 larvae per 1 m^2

7.3.3. Agronomic methods of pest control

One of the fundamental principles of integrated pest management in malting barley is preventive measures, primarily based on agrotechnical practices (see Table 10). Appropriate use of agricultural technology and the replenishment of any mineral nutrients shall improve the condition of plants in the early growth stages, when they are particularly vulnerable to attack from particular agrophage species. In addition, faster growth shall help to smother weeds which often provide a food base for some pests. Proper pre-sowing and post-sowing cultivation reduce the threat from pests, especially soil pests and those who overwinter in the soil. It is very important to implement crop rotation correctly. Many pests overwinter in the top layer of the soil or leftover plant residues. In the case of monocultures, pests after wintering have facilitated access to the food base. For this reason, spatial isolation is recommended, including from host plants of multivorous pests. Spatial isolation also helps make certain pests fly over longer distances. Appropriate measures to reduce the potential damage caused by individual pest species can also be taken at the seed sowing stage. The faster the initial vegetation stage of the plants, the more possibilities there are to anticipate the period of the greatest threat from the pests that are particularly dangerous to the emerging crops. The plant density is also important. Sowing too densely makes it easier for pests to spread, while sowing too sparsely favours weeds on which, for example, aphids thrive. The timing of the harvest is also very important — harvesting too late creates the risk of greater losses, especially in terms of yield quality. After the harvest, it is important to carry out a series of post-harvest cultivations aimed at thoroughly disintegrating plant residues (overwintering sites for certain pests), and reducing weed seeds, including perennial weeds. 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 (Mrówczyński et al. 2017, Tratwal et al. 2017).

Integrated plant protection consists in using all available methods that minimise the use of chemical plant protection products. Such a system of protection makes it possible to regulate pest numbers to a level below the economic harmfulness threshold, i.e. not endangering the crop, unlike all other methods that prevent the mass occurrence of pests by completely destroying them. The development of pro-ecological principles of plant protection against pests is particularly important, as any attempt to solve phytosanitary problems based only on a chemical method has become unreasonable and less effective. Pro-ecological principles and methods to protect most crops from pests (including pests) include, among other things, agronomic methods which are part of properly managed crop protection.

Table 10. Agronomic methods and ways to protect barley from pests

Pest	Methods and measures of protection
Wireworms	proper crop rotation, ploughing, discing, deep autumn ploughing, early sowing and increased sowing rate, weed control, spatial isolation from other cereals, root crops and brassicas
Bibionidae (march flies)	spatial isolation from other cereal plants, early seed sowing, increasing the standard of seed sowing
Bishop's Mitre	cultivation measures, spatial isolation from meadows and pastures, weed control
Ground beetle	spatial isolation from other cereal plants, increasing the standard of seed sowing, early seed sowing
Leaf miners	spatial isolation from other cereals, meadows and wasteland
Aphids	spatial isolation from other cereal plants, early seed sowing, balanced fertilisation, spraying of plants with selective insecticides, especially the edges of plantations
Cereal chafer	tillage operations, mainly deep pre-winter ploughing, spatial isolation from meadows and pastures
Nematodes	tillage operations, correct crop rotation, 5-year break in cultivation, spatial isolation from other cereal crops
Chlorops ringens	spatial isolation from other cereal crops, late sowing of winter cereals, increasing the standard of seed sowing
Grubs	ploughing, discing, harrowing, weed control, increasing the sowing rate of seeds
Frit fly	spatial isolation from meadows, pastures, grass seed plantations, control of weeds and cereal volunteers, delayed sowing of winter crops, accelerated sowing of spring crops
Gall midges	tillering operations, spatial isolation from other cereal crops, balanced fertilisation
Cutworms	spatial isolation from other cereals and crucifers and brassica vegetables, early sowing of grain, weed control, increasing the sowing rate of grain, increasing the fertilisation rate
Leafhopper	tillering operations, spatial isolation from other cereal crops, sowing of early varieties, increasing the fertilisation rate
Cereal leaf beetle	tillering operations, spatial isolation from other cereal plants, balanced fertilisation, spraying of plants, especially at the edge of the field
Snails	ploughing, discing, careful tillage, liming, destruction of weeds, spatial isolation from other cereals and crucifers and brassicas, early and deeper seed sowing, increasing the seed sowing rate
Root flies	spatial isolation from other cereal plants, early seed sowing, increasing the standard of seed sowing
Thrips	tillage, spatial isolation from other cereal plants, balanced fertilisation, plant spraying
Leafroller moths	tillering operations, spatial isolation from other cereal plants, increasing nitrogen fertilisation
Tortoise bug	cultivation measures, spatial isolation from meadows and pastures, weed control

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 barley in integrated production (IP). Messages from the Online Pest Warning System (www.agrofagi.com.pl) may be helpful. Use instructions on the label should be read before application. 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 can be found 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 on the Online 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 BREWING BARLEY

Biological methods consist of the use of natural biological agents such as: viruses, micro-organisms (bacteria, fungi) and macro-organisms (nematodes, parasitic and predatory insects and mites) to reduce the population of pests, pathogens and weeds in plant crops in the field and under covers. It should be emphasised that biological agents do not eradicate pest populations in the same way as chemical pesticides; they only reduce their populations in the long term.

In biological pest control, three main methods are distinguished:

1. introduction, i.e. the permanent establishment in new areas of natural enemies imported from other regions or continents — the classical method;
2. the use of naturally occurring and specially introduced into agricultural and forest areas landscape elements enabling and enhancing the development of populations of beneficial organisms that naturally occur in these environments — the conservation method;
3. periodic colonisation, i.e. the periodic introduction of natural enemies of a given pest, on crops that do not occur or occur in small quantities — the augmentative method.

In field crops, the use of biopreparations containing parasitic microorganisms is uncommon. First of all, there is little interest from producers in these products, as their efficacy is often much lower compared to the application of chemical plant protection products. Their effectiveness is influenced by weather conditions in the field, which often change. These include: temperature, humidity and insolation. However, it must be remembered that the introduction of these factors into the environment keeps them in it for a long time, and under favourable conditions they can limit the populations of many pests.

The biological conservation method plays a crucial role in the cultivation of spring and winter barley. It involves the modification of the agricultural landscape by humans in order to create appropriate conditions for the action of beneficial organisms occurring in the environment (Sosnowska 2018, 2022). The number of beneficial organisms can be increased, among others, by sowing melliferous plants in the vicinity of crops, leaving natural dead furrows. These sites serve as habitats for those organisms that significantly reduce populations of various pests. Hence the need to ensure an increase in the number of beneficial organisms near the crop through field scrub and flower strips. A very important element is the rational use of selective chemical plant protection products, allowing to reduce their negative effects on beneficial organisms. The decision on the need to perform chemical treatment in the field should be made on the basis of the actual threat of pests to cultivation.

The use of different cultivation techniques (e.g. non-ploughing) also promotes the development of soil-beneficial microorganisms such as insecticide and nematocide fungi. The rational use of selective chemical plant protection products is very important, allowing to reduce their negative effects on beneficial organisms. The decision on the need to perform chemical treatment in the field should be made on the basis of the actual threat of pests to cultivation.

A large role in nature is played by beneficial macro-organisms, i.e. parasitic and predatory insects, mites, and insecticidal nematodes. Under natural conditions, the importance of beneficial ground beetles is growing in integrated plant protection. They occur in large numbers in all agricultural environments, including barley crops. They are found on the top layer of soil and litter. Due to their large size, high motility and great voraciousness, they are among the most effective beneficial insects, significantly reducing the number of plant pests; among other things, they feed on eggs, pupae and larvae/caterpillars of many species of butterflies, beetles and Hymenoptera. The herbivorous corn ground beetle (*Zabrus tenebrioides*) is an exception in the family of ground beetles, considered to be a pest.

Aphids may be another problem for barley crops. In natural conditions, aphid populations are reduced by many species of predatory insects, such as ladybirds (Coccinellidae). One larva, throughout its development (approx. 30 days), can eliminate from 100 to 200 aphids. A beetle eats 30–250 aphids a day. This is a lot, but aphids develop very fast. Given that aphid flights usually occur earlier than those of ladybirds and other beneficial insects, it is necessary to decide whether chemical treatment with a plant protection product is needed. If necessary, it should be performed as early as possible, before the flight of natural enemies, or restricted to the edge strips of the plantation, or even for a spot treatment by choosing a selective insecticide. Net-winged insects (Neuroptera) also feed on aphids. Green lacewing larvae eat up to 400 aphids. However, despite enormous aphidicidal effectiveness, the high motility of these insects significantly hinders the ability to control their populations, both natural and artificially introduced into crops. Aphids are also preyed upon by species of soldier beetles (Cantharidae), gall midges (Cecidomiidae), earwigs (Dermaptera), as well as predatory insects such as specialized aphid wasps (Aphidiidae) (Tomalak 2008). Among heteropterans predatory species representing the plant bug (Miridae), minute pirate bug (Anthocoridae) and shield bug (Pentatomidae) families are of great importance.

In barley crops, snails can be a problem, which damage the embryos and endosperm of the seed sown, preventing germination and plant emergence. They can be controlled with available biological preparations having macroorganisms – nematodes – as their active ingredient. Macro-organisms are not subject to registration in Poland. Larvae of an icecticidal nemarode, *Phasmarhabditis hermaphrodita*, penetrate the gastropods' body through the respiratory canal, infecting it with bacteria and making it stop foraging after 3–5 days. The application of the agent to a moist substrate increases its effectiveness. The preparation is retained in the soil for about 6 weeks. When using nematode preparations, it is necessary to know that the sprayer should have nozzles greater than 0.5 mm, and the pressure of 300 psi should not be exceeded. The preparation contains living organisms — larvae of nematodes, so their use must be carried out especially carefully and according to the label of the product. The commercial agent may be too expensive to use on large surfaces, but the method of application should be refined.

Spiders play an underestimated role in nature. Their role is extremely important because they eliminate pests in the early period, even before the appearance of other natural enemies. Often more insects are caught in the spider's web than the predator is able to eat. Unfortunately, spiders are multivorous, so beneficial insects also fall victim to them.

Under favourable conditions (high humidity and temperatures above 20°C), insecticide Entomophthoraceae fungi ('insect destroyers') play a major role. These fungi can cause epizootic diseases, i.e. mass extinction of aphid colonies. The development of insecticide fungi is promoted by water habitats, strongly humidified habitats, forests, woodlots, rushes and meadows. Forests are more than twice as rich in insecticidal fungi as agro-ecosystems (Tkaczuk et al. 2016). Insecticides can reduce populations of wintering pests in the soil, such as wireworms and thrips. Insecticidal fungal species active in the soil include: *Beauveria bassiana*, *Metarhizium anisopliae* and *Cordyceps fumosorosea*. The effectiveness of these fungi is best at high humidity and a temperature of 25 °C. Insecticidal fungi also act on the surface of the plant. Parasitized insects are often found on leaves, such as aphids, fungus gnats, thrips, and others. Insecticidal bacteria and viruses can also play an important role. *Bacillus thuringiensis* is of particular importance from bacteria in the soil environment.

In the environment, not only beneficial insects and micro-organisms play a role in reducing harmful pest populations. It also applies to other animals, 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 useful 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. Therefore, in the integrated production of malting barley, the list of mandatory activities and treatments includes the requirement to create suitable conditions for the presence of predatory birds, which involves the installation of perching poles. Birds eat various pests.

Predatory birds living near plantations are effective in controlling small mammals (rodents, hares). To allow observation, resting poles with a minimum height of 3 m should be placed along the plantation, at least 1 per 5 hectares.

In the cultivation of spring barley, biofungicides based on parasitic fungi such as *Pythium oligandrum* may be used to combat log fusariosis perpetrators, if they are registered. The parasitic fungus *P. oligandrum* protects the root and the zones above the ground from fungal diseases. Its activity is based on destroying fungal hyphae. It is a parasite of some plant disease pathogens. Its function is to decompose pathogenic fungal hyphae by enzymatic decomposition, while stimulating the immune mechanisms of the protected plant by introducing phytohormones as well as phosphorus and sugars. The fungus works best on soils with a pH of 5.5-7.5, with a soil temperature of 12 to 25 °C. Treatments are best carried out in the morning or evening, and strong sunlight should be avoided. It is necessary to remember not to use chemical fungicides, because they negatively affect the action of the *P. oligandrum*. In spring barley cultivation, it should be applied on two occasions:

- the first treatment is performed in the spring during the tillering stage (BBCH 25-37);
- the second treatment is performed from the heading stage until the end of the flowering stage (BBCH 55-65).

Pythium oligandrum not only has protective effect, but also supplies additional nutrients to the plant through the roots. Thanks to its presence in the soil, in the root zone, plants grow stronger and healthier and their flowering is more successful. The product is environmentally safe and does not require a grace period.

<u>It should be remembered that it is not possible to ensure the protection of barley with the exclusive use of biological agents.</u> The maintenance method only supports the action of biological agents. The barley conservation strategy must include comprehensive measures based on different methods and seek to minimise the use of chemical plant protection products.

Most of the biological agents available do not guarantee better effectiveness compared to chemical agents. This depends on many factors: biotic and abiotic ones. Agricultural producers need to be trained in how such measures work, how to use them, and their relevant advantages and disadvantages. The use of these measures requires a high level of knowledge, because when incorrectly used, they often have no effect.

Advantages of biological agents and biological protection:

- security of the environment;
- enhancing the biodiversity of the agricultural landscape;
- they are safe for the consumer and beneficial organisms;
- do not require a grace period;
- once introduced into the environment, they are able to persist in the environment for a long time and can reduce pest populations without reintroduction under natural and optimal conditions for their development;
- absence of residues;
- non-toxic to entomophages;
- they are often specific to certain groups of organisms (e.g. they only infect aphids), allow to reduce the use of chemical plant protection products and protect the biodiversity of the environment.

There also are drawbacks to their use, such as: sensitivity to environmental conditions (temperature, humidity), having short life in the preparation, the need for precision treatments, slow mechanism of action.

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.

Detailed information on registered plant protection products for the protection of barley 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 at https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.

Protection of bees and other pollinators

An important element of modern plant protection is also the legal protection of bees and other pollinators during chemical treatments. Integrated pest management includes ‘the protection of beneficial organisms and the creation of conditions conducive to their occurrence, in particular pollinators and natural enemies of harmful organisms’ (Pruszyński 2007).

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.

In integrated barley production, it is important to place houses for mason bees and mounds for bumblebees. In order to create the best possible habitat for these pollinators, edges of agricultural fields are sown with melliferous plants.

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 barley 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;
- having a constant awareness that by protecting the natural enemies of barley pests, other beneficial species present in the field are also protected;
- leaving dead furrows and mid-field shelters as a habitat for many species of beneficial insects.
- reading carefully the content of the label accompanying each plant protection product and observing the information contained therein.

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 original packaging, sealed and clearly labelled, and
b) in a manner preventing these products from coming into contact with food, drink or feed;
c) 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,
- entering sewerage systems, except for a separate no-return sewerage system equipped with a sealed sewage storage tank or with sewage neutralisation facilities;

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 spaces should be clearly marked (e.g. with a notice: '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 handling of plant protection products, in accordance with the principles of **Good Plant Protection Practice.**

Devices 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 adjustments of the sprayer make it possible to choose the optimal parameters of the treatment. In accordance with good plant protection practice in terms of the adjustment (calibration) process of the sprayer, the type and dimension of the sprayers and the working pressure should be determined so that they ensure the application of the intended 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 sprayed 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 production, the volume of spray (l/ha) should be selected based on available catalogues, training materials and handbooks or other thematic papers. Determination of spray liquid volume should take into account factors such as the type of crop to be sprayed, the development phase of the plants, the density of the crop, the possibility to use different spraying techniques (type of treatment apparatus, type and kind of spraying equipment), as well as the recommendations included in the label of the specific plant protection product.

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 intended to be covered by the treatment, and may cause unintended poisoning of many beneficial species of entomofauna.

Table 11. presents 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 11. Limit and optimal meteorological conditions for plant protection treatments

Parameter	Acceptable values	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 over the field should be made very precisely to avoid strips being left unsprayed and so that no overlapping of the sprayed liquid occurs on already sprayed areas.

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 non-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 residual liquid drained from the sprayer must be disposed of using technical equipment that ensures biodegradation of the active substances contained in 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.

The law 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 the 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

Preparation for harvesting

The plantation to be harvested should be properly prepared. The field surface should be level, and cleared of stones and objects that could damage the harvesting unit mechanisms. Field edges should be checked and cleaned and obstacles that are difficult to see by the harvester operator should be marked, i.e. waterlogged areas, concrete survey posts, drainage wells, etc. Adequate preparation of the plantation facilitates the organisation of the harvest, streamlines the harvesting process, reduces combine harvester failures and increases work safety.

Harvest

The harvester should be fully operational before harvesting. Particularly in the case of barley harvesting, the condition of the threshing unit should be checked. A thresher in good condition guarantees that awns are properly removed from the grain. Worn-out semicircular threshing machines and a worn threshing floor lead to a decline in threshing quality. If this is the case, the threshing bars on the threshing drum should be replaced before the start of the season and the threshing floor regenerated. In order to reduce losses or excessive grain contamination, appropriate adjustments to the combine harvester must be made: concave clearance, drum speed, louver sieve openings, and fan speed (Choszcz & Konopka 2000, Bieniek 2011).

Barley should be harvested at the full maturity stage of the grain, when it has reached 14-15% moisture content. Overly dry grain with a moisture content of less than 13% is prone to mechanical damage. Delaying harvesting will result in fungal infestation of the kernels. In addition, mature barley has a tendency to break at the end of the ear, leading to losses due to ears falling to the ground.

Barley is more difficult to thresh than other cereals because of the awns that stick out of the grain. The barley grain must be thoroughly cleaned of them. The awns that are not removed from the threshing unit also increase the loss of grain in the straw that goes with it into the stubble.

Obtaining clean barley grain is possible if several rules are followed. First of all, harvesting should begin when the plants are mature and completely dry. Sometimes, despite the dry grain, the straw and parts of the ears may still be insufficiently dry. The straw should be dry and brittle (Choszcz and Konopka 2000, Bieniek 2011).

When harvesting with a combine harvester, it is important to pay attention to the weight of the grains in order to adjust the air flow rate accordingly and to remember to connect the spikelet mechanism. If there is still a high proportion of grains with awns in the harvester's hopper, its operating parameters can be changed. To do this, the working gap between the drum and the threshing floor must be reduced. This treatment leads to a more aggressive impact of the thresher elements on the grain and is most often effective in improving threshing quality. It is also possible to increase the operating speed of the harvester so that the amount of material between the drum and the threshing floor increases, thereby increasing the frictional force within the threshed material (Choszcz i Konopka 2000).

With these changes in operating parameters, it is important to remember not to increase the proportion of grain damage by threshing more thoroughly. This is particularly important for brewing barley, which requires careful threshing. During the harvesting of dry barley grain for brewing purposes, it is advisable to reduce the speed of the thresher drum in order to limit micro-damage to the germ and whole grain that causes, in particular, a deterioration in germination, which can lead to disqualification of the raw material when purchased due to poor quality.

Special covers mounted under the threshing floor of the main threshing drum and the inclusion of a threshing bar to intensify the effect of wiping the grain clean of any remaining awns also improve the threshing effect (Przybył and Sęk 2010).

Claas combine harvesters can be equipped with a clamping slat, or the covers can be closed under the pre-floor and additionally a clamping slat can be installed between the pre-floor and the main one. New Holland CX Series combine harvesters can be equipped with special locking strips. In John Deere T-series combines, a BoosterBar is installed on the threshing drum, increasing barley yield by up to 10%. The John Deere W-series combine harvesters have a BoosterBar and the ability to close three sections of the threshing floor for better awn breakage. Also, John Deere rotor harvesters of the series are equipped with special rotor covers to ensure proper awn breakage. Awns may also be removed during post-harvest processing of the grain.

Grain transport

The means of transport used to transport the harvested barley grain should be tight, clean, dry, free from pests and foreign odours, and secured with tarpaulin to protect the grain from getting wet and transport losses. Means of transport generally do not cause damage to the grain. However, this can occur during post-harvest processing of the grain, so for internal transport at grain reception points, it is recommended to use pneumatic conveyors in storage facilities.

Post-harvest treatment

Immediately after harvesting, even before the grain is put into storage, it should be cleaned of impurities. Any organic contaminants (seeds, weed parts, broken kernels, green parts of plants) have a higher moisture content than grain, and therefore may contribute to the development of bacteria, mould or pests during grain storage. The purity of the grain affects the course of the possible drying process in a fundamental way. At the initial drying stage, the temperature of the grain should not exceed 35 °C, and at the end of drying it may rise to 40 °C.

Subsequent post-harvest processing depends on the intended use of the barley. Barley is used for consumption, brewery and feed purposes. A desirable characteristic of feed grains is high protein content, the opposite of brewing grains, which in turn should have high accuracy and uniformity.

The basic requirements for malt grain according to PN-R-74109 are humidity up to 15%, impurities up to 3% and equalisation of more than 90%. The grain should have a uniform colour, slightly shiny, thin and gently wrinkled skin. The protein content in the dry matter of the grain should be up to 11.5%. Germination energy is also important; it should be more than 95% for quality class I.

The grains for consumption should be healthy, of good nutritional quality, low in husks and shallow rubble, fully mature, native, uniform in size, not overgrown and free from mycotoxins and pests, weed seeds content up to 1%, foreign grains up to 3%, moisture content up to 15% and uniform colouring with natural gloss of the chaff.

In the process of thorough cleaning, the grains must be brought up to the quality parameters specified by the standards or to the quality requirements set by the customers. Relatively high efficiency of the grain cleaning process can be achieved on a process line consisting of a windrower, sorter, and cylindrical screening device.

Storage

The vital processes of respiration and oxidation take place in the grains. After the grain has reached full maturity, they are still quite intense. Harvesting does not interrupt these processes. During the respiration process, the free simple sugars are broken down into water and carbon dioxide and heat is given off, with so-called 'sweating of the grain' and an increase in the grain's temperature being the symptoms of this process. It is referred to as post-harvest ripening. As a result, the quality characteristics of the grain are finally established. This process should be controlled by measuring the temperature in the grain heap and ventilating it if necessary.

Barley grains are stored in flat storage facilities and silos, with long-term grain storage usually taking place in silos (Ryniecki i Szymański 1999). The main determinants of safe grain storage include: grain moisture content, storage temperature, contamination levels, air contact and degree of damage to the grain cover. The safe moisture content of grain for storage is below 14 %. If a longer storage of barley after harvest is expected, it should be dried to a moisture content of 11–12 % (Kaleta i Górnicki 2008).

During storage, it is necessary to control the microclimate conditions so that the grains are not exposed to moisture and settlement by fungi. An inspection is also needed in silos and cereal storage facilities to detect the possible presence of pests (Ryniecki i Szymański 1999).

12. DEVELOPMENTAL STAGES OF BREWING BARLEY BASED ON THE BBCH SCALE

In the development of barley (*Hordeum vulgare* L.) all the 10 major developmental phases are present: 0 — Germination, 1 — Leaf development, 2 — Tillering, 3 — Stem elongation, 4 — Swelling of the leaf sheath of the flag leaf, 5 — Earing, 6 — Flowering, 7 — Kernel development, 8 — Ripening, 9 — Senescence. The intervals between stages, the number of leaves, and the height of the plants at each stage depend on individual variety characteristics and agro-ecological factors. The first tillering stage usually occurs when the plant already has 3 or 4 leaves. When stem elongation begins, the plant completes tillering, the stem straightens and the leaf sheaths thicken. Tillering is already completed before the stem-elongation stage. For winter cereals, stem elongation marks the transition of the plant from the vegetative to the generative stage as evidenced by the microscopic structure of the ear the beginnings of which are already formed during the formation of the 4th, 5th, or 6th leaf. At this stage of development, the number of spikelets per ear and thus the final size of the ear is already determined. In the longitudinal section of the main stem, a small spikelet is visible which is gradually pushed up towards the top of the stem as more internodes appear. The flag leaf usually appears when there are at least 3 nodes above the soil surface. During the BBCH 31–33 development stages, the highest growth dynamics of the plant are observed. Care should be taken not to confuse the first proper node with the tillering node. The appearance of the flag leaf buds marks the end of stem elongation as the plant enters the heading stage. An inflorescence and eventually an ear is visible in the flag leaf sheath.

CODE DESCRIPTION

Principal growth stage 0: Germination

00 Dry seed (caryopsis)
01 Beginning of seed imbibition, soft kernel of a typical size
03 Seed imbibition complete, swollen kernel
05 Radicle has emerged from caryopsis
06 Radicle elongated, root hairs and/or side roots visible
07 Leaf shed (coleoptile) emerged from the kernel
09 Coleoptile breaks through to the soil surface (soil cracking)

Principal growth stage 1: Leaf development[1],[2],[3]

10 The first leaf emerges from the leaf sheath (Coleoptile) (pinning)
11 1 leaf stage
12 2 leaves stage
13 3 leaves stage
14 4 leaves stage
15 5 leaves stage
1. These stages continue until…
19 Stage of 9 or more leaves

Principal growth stage 2: Tillering

20 No tillers
21 Beginning of the tillering stage: 1st tiller visible
22 2 tillers detectable
23 3 tillers detectable
2. Stages continue until…
29 End of the tillering stage. Maximum no. of tillers detectable

Principal growth stage 3: Stem elongation

30 Beginning of stem elongation: pseudostem and tillers erect, first internode begins to elongate, top of inflorescence at least 1 cm above tillering node
31 Node 1 at least 1 cm above tillering node
32 Node 2 at least 2 cm above node 1
33 Node 3 at least 2 cm above node 2
3. Stages continue until…
37 Flag leaf just visible, still rolled
39 Flag leaf stage: flag leaf fully unrolled, ligule just visible

Principal growth stage 4: Swelling of the leaf sheath of the flag leaf (development of ears in the leaf sheath)

41 Beginning of thickening (swelling) of the flag leaf sheath, early stage of ear development
43 Mid boot stage: flag leaf sheath just visibly swollen
45 Final stage of swelling of the flag leaf sheath, late stage of ear development

47 Flag leaf sheath opening
49 First awns visible

Principal growth stage 5: Earing

51 The beginning of earing: tip of inflorescence emerges from the sheath, first spikelet just visible
52 20 % of the inflorescence emerged
53 30 % of the inflorescence emerged
54 40 % of the inflorescence emerged
55 50 % of the inflorescence emerged
56 60 % of the inflorescence emerged
57 70 % of the inflorescence emerged
58 80 % of the inflorescence emerged
59 End of heading, all spikelets emerge from the sheath, the ear is fully visible

Principal growth stage 6: Flowering

61 Beginning of the flowering stage: first anthers visible
65 Full flowering: 50% of anthers mature
69 End of flowering: all the spikelets have completed flowering but some dehydrated anthers may remain

Principal growth stage 7: Kernel development

71 Water maturity: the first watery grains have reached half their typical size
73 Early milk
75 Medium milk: grain content milky, grains reached final size, still green
77 Late milk

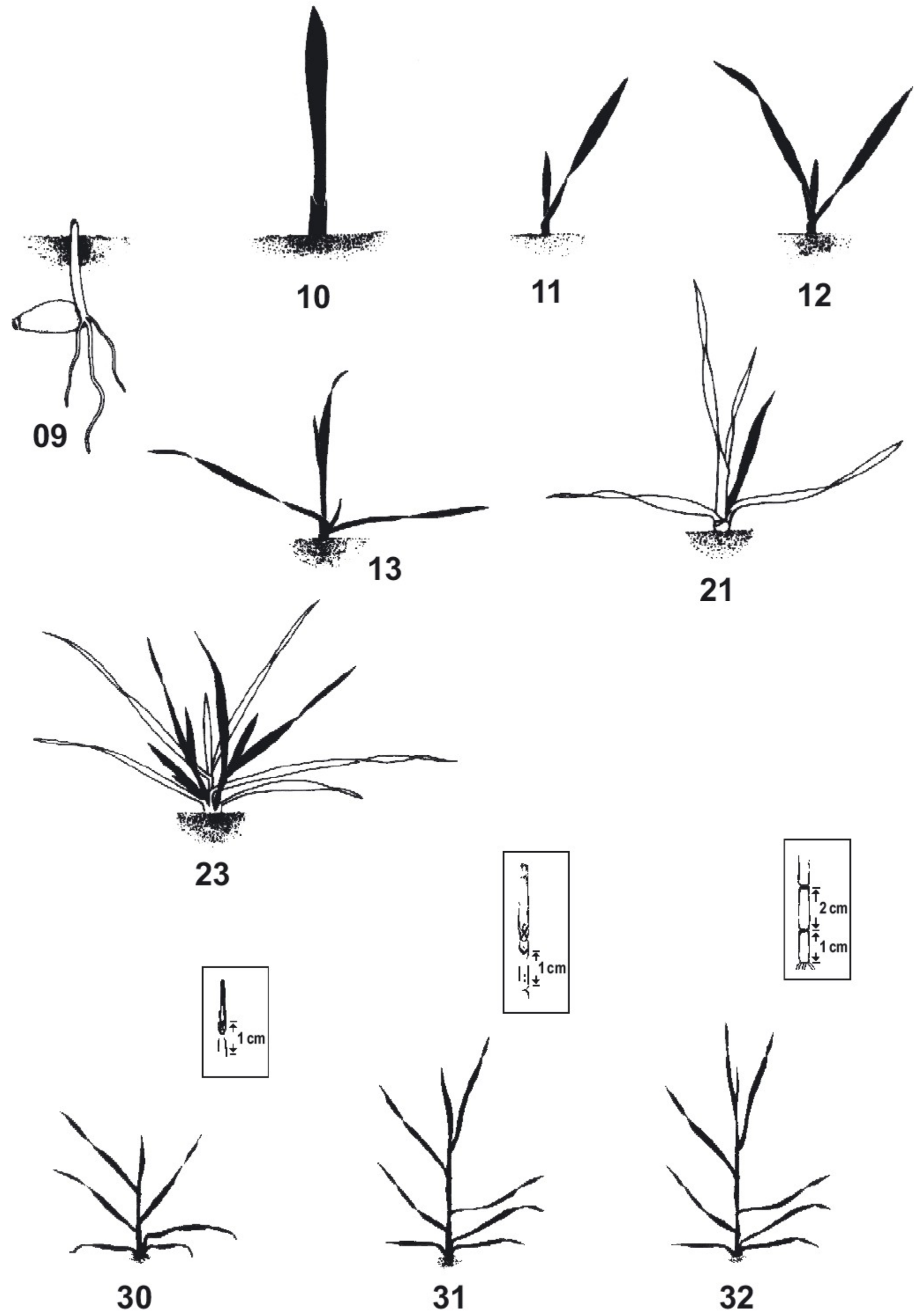
Principal growth stage 8: Ripening

83 Beginning of waxy maturity of the kernels
85 Soft waxy maturity, grains easily smeared between the fingers
87 Hard waxy maturity, grains easily broken with a fingernail
89 Full maturity, hard grains, difficult to split with a fingernail

Principal growth stage 9: Senescence

92 Over-ripe: very hard grains, cannot be dented by a fingernail
93 Grains loose in the ear, may fall off
97 Plant dead and collapsing
99 Harvested product, resting period

[1] A leaf is developed when its ligule or the tip of the next leaf is clearly visible
[2] Tillering or elongation of the stem may occur earlier than in Phase 13, then the description is continued in phase 21
[3] If the stem elongation phase begins before the end of the tillering phase, then the description is continued in phase 30.



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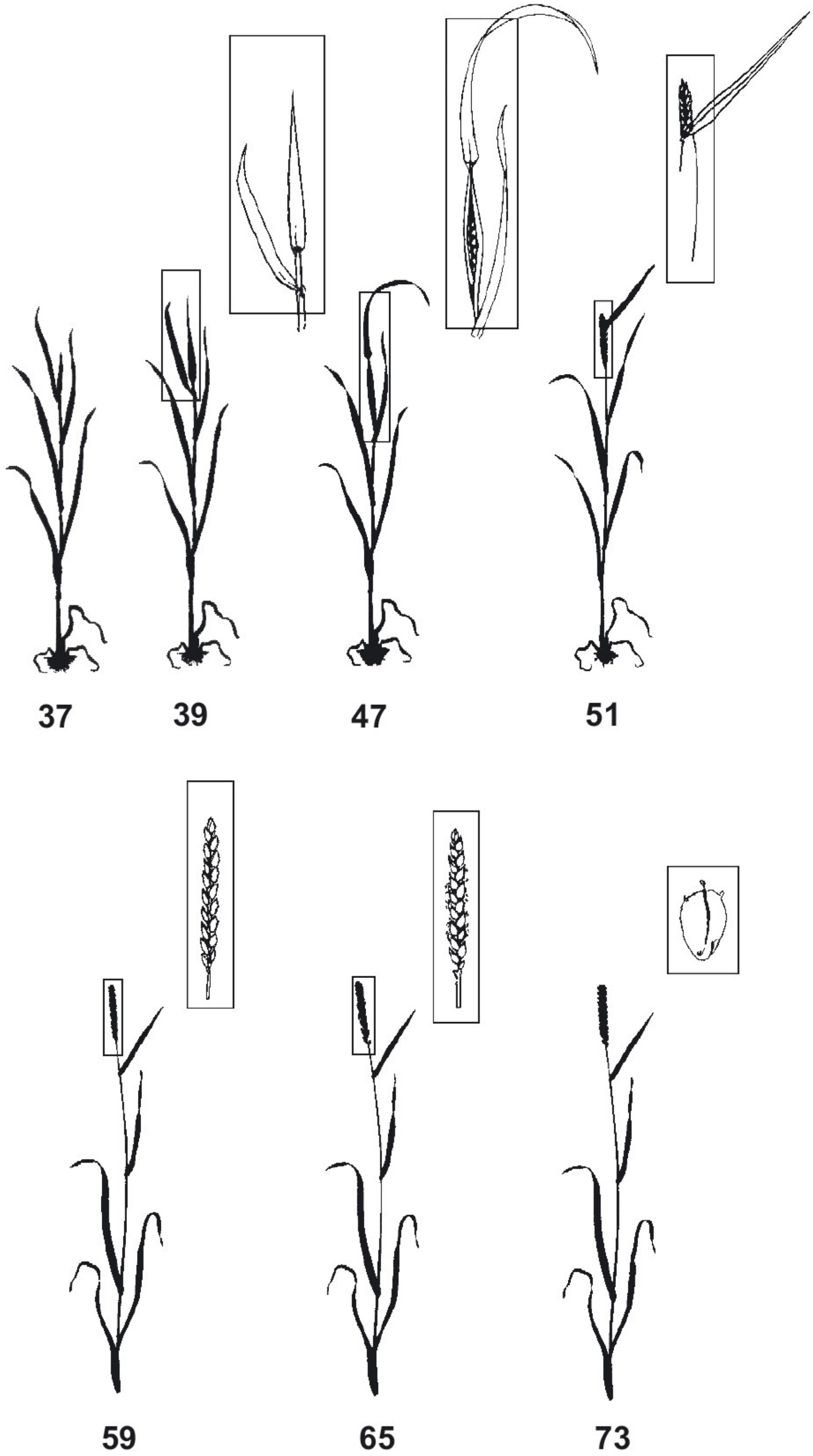
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13. RULES FOR KEEPING RECORDS IN INTEGRATED PRODUCTION

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 the Implementing Regulation (EU) 2023/564.

Other documents that a 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 integrated plant production application 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 used in integrated production — all cultivated varieties submitted for IP certification must be recorded in the table containing the list of fields.

Field plan with biodiversity-increasing elements — a graphical map of the holding and its immediate surroundings with the proportions of the various 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). All devices and persons performing treatments, including those performed by a service provider, must be listed 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 stickers, pheromone traps — in this table the used colour sticky boards, pheromone traps, etc. must be recorded with an indication of the 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 is to be filled in by entering information about the purchased material: species, variety, degree of qualification, quantity, and proof of purchase (invoice, official label or marketing operator label).

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 method — a page in the Notebook containing space for IP producer’s comments concerning the requirements for pest management 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 with the IP producer’s space for information relating to the cleaning of machinery, devices and equipment used in the production, which is required in 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 filled out application for a certificate attesting to the use of integrated plant production, the plant producer provides the certifying body with a declaration that the cultivation has been carried out in accordance with the requirements of integrated plant production, and information on the species and varieties of plants grown in line with the requirements of integrated plant production, the area of their cultivation and the yield size.

LIST OF MANDATORY ACTIVITIES AND TREATMENTS IN THE INTEGRATED PRODUCTION (IP) OF BREWING BARLEY

Mandatory requirements (compatibility of 100%, i.e. 13 points)			
Item	**Control points**	**YES/NO**	**Comment**
1.	Use of appropriate crop rotation (including very good and good pre-crops) – indicated in the methodology **(Chapter 3.3.**)	☐/☐	
2.	Selection of varieties recommended by the COBORU (**see Chapter 4**)	☐/☐	
3.	Use of at least certified seed material, treated in accordance with the ESTA standard or an equivalent standard – certified seeds **(Chapter 7.2.).***	☐/☐	
4.	Analysing soil pH and the content of the main nutrients (NPK and Mg) according to the cycles indicated in the methodology confirmed by documents (**Chapter 6).**	☐/☐	
5.	Application of macro- and micronutrient of fertilisation at the appropriate times and doses, depending on the type and pH of the soil, following a nutrient balance carried out according to the indications in the methodology (**Chapter 6.3.**)	☐/☐	
6.	Use of agronomic methods as the first step in weed control and, in the case of a chemical control necessity, the correct application of herbicide at the right dose, taking into account the level of susceptibility of the weeds determined for individual weeds or their groupings (**Chapter 7.1.).**	☐/☐	
7.	Monitoring of the field from emergence to the beginning of maturation at least once a week for the occurrence of diseases (powdery mildew of cereals and grasses, net blotch of barley, barley rust, cereal rhodchosporiosis) and after earing with particular attention to fusarium ear blight (**see Chapter 7.2.**)	☐/☐	
8.	Systematic monitoring of the field from emergence to propagation 1 × per week for the presence of aphids – virus vectors, and from the beginning of the pollination phase to maturation, observation for the presence of violin and foot-and-mouth disease 1 × per two weeks (direct plant vetting, yellow vessels, etc.) (**see Chapter 7.3.)**	☐/☐	
9.	When pest and disease threshold values are exceeded, use of plant protection products (using the Pest Signalling Platform or other decision support systems) (**see Chapters 7.2.4. and 7.3.2.**)	☐/☐	
10.	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).**		
11.	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).**	☐/☐	
12.	Alternating use of active substances of plant protection products from different chemical groups to prevent resistance of agrophages (weeds, pests and pathogens) (**see Chapter 7.**)	☐/☐	
13.	Harvest at the right time (correct grain moisture) (**see Chapter 11.**)	☐/☐	

* Certified seed treated other than in accordance with the ESTA or equivalent standard may be used for sowing in the period 2025–2026.

Note:

The fulfilment of all the requirements in the list of mandatory actions and treatments under the integrated production scheme must be documented in the Integrated Plant Production Notebook.

14. CHECKLIST FOR AGRICULTURAL CROPS

Basic requirements (100 % compliance, i.e. 28 points)			
Item	**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 is up-to-date?	☐/☐	
6.	Does the producer systematically monitor the crops and record them in a 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?	☐/☐	

Basic requirements (100 % compliance, i.e. 28 points)			
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 their qualifications to apply plant protection products?	☐/☐	
11.	Are the applied plant protection products authorised for use in a given plant crop?	☐/☐	
12.	Is each use of plant protection products recorded in the IP notebook taking into account the reason, 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 plant protection products used for the treatments respected whenever 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 label instructions concerning the precautions related to environmental protection, i.e. e.g. the observance of buffer zones and safe distance from areas not used for agricultural purposes?	☐/☐	

Basic requirements (100 % compliance, i.e. 28 points)			
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 respected?	☐/☐	
21.	Are the sprayers listed 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?	☐/☐	
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)			
Item	**Control points**	**YES/NO**	**Comment**
1.	Have the plant varieties grown been 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 agronomic procedures in accordance with the IP methodologies?	☐/☐	
4.	Is the recommended catch crop used in cultivation?	☐/☐	
5.	Are actions taken on the holding to reduce soil erosion?	☐/☐	
6.	Are sprayers specified in the IP Notebook used for the treatment?	☐/☐	
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)			
Item	**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		

15. FURTHER READING

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