MAIN INSPECTORATE FOR PLANT HEALTH AND SEED INSPECTION

DRAFT

Methodology for the integrated production of sugar beet (*Beta vulgaris* L.)

(second edition)

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by
the Main Inspector for Plant Health and Seed Inspection

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1. PREFACE

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

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

Professional users who apply plant protection products are obliged to take into account the requirements of integrated plant protection. Sn agricultural producer should use all available measures and methods of protection against pests before applying chemical plant protection methods with a view to reducing the use of pesticides. They consist in the application of crop rotation, the use of appropriate varieties, compliance with optimal timing, the application of appropriate agronomic practices, appropriate fertilisation, and the prevention of the spread of pests. One of the requirements is also to protect beneficial organisms and create favourable conditions for their occurrence, in particular pollinators and natural enemies of pests. The use of chemical plant protection should be preceded by monitoring activities and supported by appropriate scientific instruments and advice.

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 complicated 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 necessary resources needed for plant growth and development to create an environmentally safe system while ensuring high-quality crops free from residues of substances known to be harmful (heavy metals, nitrates, plant protection products).

More information on notification to the integrated plant production system and rules for issuing IP certificates is available on the website of the National Plant Protection and Seed Inspectorate at https://www.gov.pl/web/piorin/zasady-ip.

2. CLIMATE AND SOIL REQUIREMENTS AND SITE SELECTION

2.1 Climate

Sugar beet is a temperate climate zone plant, and its cultivation depends on soil quality. It is a plant that is not sensitive to short-term ground frosts, but they slow down its development. Frost damage can occur when it occurs during the sprouting stage to the soil surface – pinning – (BBCH 09).

The highest demand for water occurs between May and July, and then decreases. Water shortages during this period result in a decrease in yield height and quality. Particularly noticeable losses are observed on weaker soils. Intensive growth and proper development take place at 15-30 ºC.

2.2 Soil

The soil quality is a very important factor for sugar beet cultivation. Higher and more reliable yields are obtained on soils classified as wheat complexes and very good rye complexes. In the agronomic category, these are the following classes of soils: I, II, and III. Lower, but still satisfactory, yields can be successfully achieved on lighter soils, provided that these have a more compact substrate. These soils belong to the good rye complex. When deciding to grow beet on lighter soils, care must be taken to ensure that the soils are well cultivated. The sites where sugar beet is to be grown must be nutrient-rich, abundant in organic matter and humus, with a balanced water-to-air ratio and a suitable pH level that is close to neutral or slightly acidic.

2.3 Precursor crops

When growing sugar beet in integrated production, it is absolutely necessary to respect the break in cultivation at the same field. It must be at least three years. This means that beet cannot be grown on the same field again until the fourth year. Observing this break is fully justified, as growing beet too frequently on the same field leads to soil depletion due to the proliferation of pests, mainly nematodes, as well as pathogen survival structures that cause serious root and leaf diseases. In integrated production, precursor crops are divided into three categories: best, good and worst. When growing beet in the integrated production system, the crop may only be planted after the best and good precursor crops. Beet must not be grown in the integrated production system following the worst precursor crops.

<u>Best precursor crops</u>: winter and spring wheat, winter and spring barley, triticale, rye and oats (grown on soils suitable for sugar beet cultivation), legumes, edible and forage peas, vetch, field beans, soya, white lupin, narrow-leaved lupin and yellow lupin (provided they are grown on soils suitable for sugar beet cultivation), vegetables such as: beans, cucumbers, tomatoes and onions.

<u>Good precursor crops</u>: maize, sunflower, table potatoes, starch potatoes, mustard, blue guy, buckwheat (provided it is cultivated on soils suitable for the cultivation of sugar beet).

<u>Worst precursor crops</u>: winter and spring rapeseed, clover, alfalfa, and perennial grasses.

3. SELECTION OF BEET VARIETIES IN INTEGRATED PRODUCTION

All registered sugar beet varieties are characterised by high productivity, both in terms of yield and sugar content. Thanks to advances in breeding, more and more varieties with increased resistance or tolerance to certain diseases and pests are available to producers. In areas at high risk of cercospora leaf spot of beet outbreaks, varieties with increased resistance to the disease (Cr+) should be grown in particular. Beet cyst eelworm tolerant varieties should be grown in mushy fields with live egg and larvae contents above 500 pcs./100 g soil. The selection also includes varieties with increased resistance to other diseases such as root rot. In accordance with bilateral agreements between sugar producers and growers, jointly selected varieties of beet are grown in the regions of individual sugar factories. Growers also have the option to purchase varieties outside the agreed lists, provided they are registered in Poland or included in the Community list.

For the establishment of a sugar beet plantation, seed of at least the certified category must be used. The recommended varieties are included in the list of varieties compiled by COBORU (Centralny Ośrodek Badania Odmian Roślin Uprawnych, Research Centre for Cultivar Testing). This list is maintained by COBORU. Plantations managed in the integrated production system may also be established using varieties listed in the CCA catalogue, provided that the choice is justified in accordance with the objectives of IP (the variety must be resistant to a biotic or abiotic factor).

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

4. PRE-SOWING TILLAGE AND SOWING

Sugar beet fields should be prepared in autumn. Immediately before sowing, the soil should be cultivated with a cultivator to the depth of sowing so that the seed lies on an intact layer of soil. In general, sowing should be done at a depth of no more than 2-3 cm.

4.1 Soil cultivation

Work on preparing the field for sugar beet cultivation should start early, immediately after the harvest of the precursor crop. The type of cultivation and its elements vary greatly depending on the technology in which the beet will be grown. In the integrated production, beet can be grown using both traditional ploughing and conservation tillage systems. However, it is prohibited to grow beet using the zero-tillage system. Depending on the technology, the tillage consists of different treatments.

The traditional ploughing system consists of the following:

– post-harvest tillage — must be carried out carefully so that all post-harvest residues are well and finely shredded. This is due to the fact that pathogens and pests may exist on their surface. Furthermore, thorough post-harvest tillage helps to reduce evaporation, thereby protecting the soil from water loss. As a result of professionally carried out tillage, weed seeds are stimulated to germinate, and the emerging weeds are mechanically destroyed through subsequent treatments;
– subsoiling – this treatment is not mandatory in the preparation of the field for the cultivation of beet in the integrated production system. However, if the plough pan needs to be eliminated, it should be carried out;
– pre-winter ploughing – ploughing should be carried out to the depth of the humus layer, which, depending on the soil type, is 25–30 cm;
– spring tillage – the spring preparation of the field should start as soon as it is possible to enter the field. The first works aim to secure the water accumulated in the soil profile during the winter, as well as to accelerate the heating of the soil. Subsequent tillage perations aim to prepare the soil for placing the seed. The operation of the cultivation unit must not be too deep and must not cause excessive pulverisation of the soil. After tillage, the soil should be re-compacted to a depth of 2–4 cm.

Conservation tillage consists of the following:
– post-harvest tillage — must be carried out carefully so that all post-harvest residues are well and finely shredded. This is due to the fact that pathogens and pests may exist on their surface. Furthermore, thorough post-harvest tillage helps to reduce evaporation, thereby protecting the soil from water loss. As a result of professionally conducted tillage, weed seeds are stimulated to germinate. The emerging weeds are destroyed during the next tillage treatment. This treatment is slightly different from post-harvest tillage in the traditional ploughing system, as during its execution the field should be well levelled and catch crops sown. Catch crops should be sown at the turn of August and September. They should include plants that deter cyst nematodes. Most often, the catch crop mixture includes the following plants: mustard (nematode-resistant), oilseed radish, phacelia, and various legumes. Catch crops left in the ground over winter are destroyed by low temperatures, and their residues form a mulch that protects the soil from wind and water erosion, as well as from the leaching of nutrients;
– spring tillage – in conservation tillage, spring tillage varies depending on how the mulch is handled. In the event of its destruction, a cultivation unit should be used to mix mulch and mineral fertilizers with the soil, as well as to prepare the soil for sowing. If the mulch is left in place, sowing is carried out directly into the mulch using a precision seeder equipped with coulters;
– strip tillage – consists of loosening the soil belt without inverting it. This tillage involves sowing seeds and applying mineral fertilisers. The use of strip tillage leads to a significant reduction in costs and helps to conserve the soil’s water resources.

4.2. Beet sowing

For sowing, use seed of at least the ‘qualified’ category and retain proof of purchase, labels and, in the case of small EC packages where the label is printed on the packaging, the entire package for inspection purposes.

4.2.1 Sowing time

Beet sowing should begin when the temperature at a depth of 5 cm is not lower than 5 ℃.

Beet sowing must be carried out using a precision seeder. The seeds should be sown in a row, 16–20 cm apart, at a depth of 2–3 cm. The spacing between plants in a row depends on the site. Denser sowing, at 16 cm intervals, should be used on poorer, less-prepared sites; while wider spacing, at 18–20 cm, is appropriate for good, well-cultivated, properly prepared soils. The distance between rows must be 45 cm. This is due to the standardisation of equipment for harvesting beet.

4.2.2. Sowing standard

Table 1. Beet sowing standards (number of sowing units/ha)

Sowing density in cm	Seed requirement in units*
16	1.4
18	1.2
20	1.1

* seeding unit (s.u.) = 100 000 seeds

5. SUSTAINABLE BEET FERTILISATION SYSTEM

In integrated production, fertilisation is determined on the basis of a nutrient balance before each crop, and soil testing is conducted at least every 4 years in accredited laboratory (and confirmed by documents).

The use of the yield-forming potential of plants depends to a large extent on optimum plant nutrition. In a sustainable system, fertiliser doses are a resultant of the nutritional needs of the plants, the abundance of soil, the high quality of the crop, the profitability of production and environmental requirements.

Sustainable fertilisation ensures that the plant is supplied with all the necessary nutrients in the right quantity, time and form, which in turn is a prerequisite for high yields of the desired quality. In addition, it realises several other important natural, social and economic aspects. The most important are:

- maintaining soil fertility at a high level by improving its physical, chemical and biological properties,
- protecting the environment by minimising losses of fertiliser nutrients outside the soil-plant system,
- increasing plant resistance to diseases and pests,
- production of high-quality crops that are safe for consumers,
- ensuring high efficiency and cost-effectiveness of the fertilisers used.

5.1. Beet nutritional requirements

Beet, due to its very high biomass production potential (roots + leaves), has relatively very high nutritional requirements (Table 2). It yields best on soils with at least an average content of phosphorus, potassium, and magnesium with good structure and regulated pH. It is a plant that responds more strongly to soil abundance than to current fertilisation.

Table 2. Average macro- and micronutrient uptake of sugar beet per tonne of main crop with corresponding amount of by-product

Macronutrient uptake in kg						Micronutrient uptake in g			
N	**P**	**K**	**Mg**	**Ca**	**S**	**B**	**Cu**	**Mn**	**Zn**
3.5	0.7	5.4	1.1	5.0	1.0	7	3	28	14
–	1.6*	6.5*	1.8*	7.0*	1.9*	–	–	–	–

*calculated to oxide forms

Source: http://iung.pl/dpr/potrzeby.html

5.2. Soil pH

Apart from humus, soil pH is the primary indicator of soil fertility. Maintaining acidity at the optimal level under given habitat conditions has a beneficial effect on the assimilation of macro- and micronutrients, the activity of microorganisms, the rate of mineralisation and humification processes of organic matter and the durability of soil structure, thus determining the effectiveness of mineral fertilisation.

Beet is a very reaction-sensitive plant and thrives best in soils with a slightly acidic to neutral pH (6.0-7.0). Growing beet in acidic sites increases the risk of seedling blight and reveals the toxic effects of aluminium and manganese compounds on the root system.

Lime doses depend on the agronomic category of the soil and the pH value that in turn determine the classes of liming needs (Table 3), on the basis of which lime doses are determined (Table 4).

Liming should be performed after harvesting the precursor crop. This timing allows the fertiliser to be well mixed with the soil in the course of subsequent cultivation operations, which, in addition to the chemical form and crumbling of the lime, determines the effectiveness of the treatment.

Table 3. Assessment of soil liming needs

Assessment of liming needs	Soil agronomic category and reaction (pH)			
	very light	**light**	**medium**	**heavy**
	pH in 1 mol KCl			
Necessary	up to 4.0	up to 4.5	up to 5.0	up to 5.5
Needed	4.1–4.5	4.6–5.0	5.1–5.5	5.6–6.0
Recommended	4.6–5.0	5.1–5.5	5.6–6.0	6.1–6.5
Limited	5.1*–5.5	5.6*–6.0	6.1*–6.5	6.6*–7.0
unnecessary	from 5.6	from 6.1	from 6.6	from 7.1

*optimal pH values for soil agronomic categories

Source: http://iung.pl/dpr/wapnowanie1.html

Table 4. Lime doses in terms of CaO in t/ha depending on liming needs

Agronomic category of the soil	Assessment of liming needs			
	necessary	**needed**	**recommended**	**limited**
Very low	3.0–1.5*	2.0	1.0	–
Light	3.5–2.0*	2.5	2.0	–
Medium	4.5–3.0*	3.0	2.5	1.0
heavy	6.0–4.0*	4.0	3.0	1.5

*The maximum CaO doses that can be used at a time are given in brackets. The liming treatment with a supplementary dose can be repeated after one year, once the current pH value of the soil has been determined.
Source: http://iung.pl/dpr/wapnowanie1.html

5.3 Macro- and micronutrient fertilisation

The fertilisation plan should be drawn up in accordance with the principles of good agricultural practice, on the basis of the chemical composition of the fertilisers and the nutritional needs of the plants, as well as the richness of soil, taking into account the natural and organic fertilisers used. No obligation to test the soil for micronutrients exists, and their application during the growing season is determined by the nutritional requirements of sugar beet.

5.3.1 Nitrogen fertilisation

Nitrogen is the main yield-forming component. It is a component of amino acids, nucleic acids, energy storage compounds (ATP), chlorophyll and some phytohormones. It stimulates the growth of roots and aboveground organs to which it imparts an intense green colour. It plays a key role in growth and is involved in most of the biochemical reactions taking place in the plant.

Over-fertilisation with nitrogen leads to overproduction of aboveground biomass accompanied by poor root growth. The leaves have a large surface area, are delicate and intensely green. Plant resistance to diseases and pests is reduced. Even when harvested late, the roots are technologically immature, with lower weight, reduced sugar content, and high α-amino nitrogen. Therefore, nitrogen fertilisation of beet should be at a moderate level, adapted to the habitat conditions.

Nitrogen doses according to the ‘Nitrates Programme’ guidelines must be consistent with the nitrogen fertilisation plan. The first dose of 70-100 kg N/ha or 50% of the total is sown before the cultivation unit and the remaining part at the stage of 2-3 pairs of true leaves. A simplified nitrogen balance according to the following formula shall be used to calculate the dose of mineral nitrogen fertilisers:

N min rate = on-farm achievable yield [t/ha] × unit nitrogen uptake [kg N/t] – ∑N from other sources × fertiliser equivalent – correction for crops grown after a precursor crop or catch crop of leguminosae/0.7.

5.3.2 Fertilisation with phosphorus and potassium

Phosphorus is involved in many vital plant functions, above all in energy metabolism. It is involved in photosynthesis, carbohydrate, protein and fat synthesis. It influences root growth dynamics, increases nutrient uptake, plant resistance to stresses such as low temperatures, water shortages, or pathogen infestation.

Potassium is a strategic ingredient for the beet. It is uptaken in the largest quantities. It takes an active part in nitrogen management and thus has a major impact on nitrogen efficiency. It influences the efficiency of photosynthesis and determines the rapid transport of assimilates from the leaves to the roots, which is crucial for beet. It participates in the regulation of water and gas metabolism, increases cell turgor and plant drought resistance. It ensures the proper development of mechanical tissues, thus increasing plant resistance to diseases and pests.

In fertilising beet with phosphorus and potassium, the aim should be to bring the soil's phosphorus and potassium abundance to at least an average level the year before beet cultivation. It is assumed that the critical value for phosphorus regardless of the agronomic soil category is 15 mg P_2O_5/100 g,while it is 15, 20, and 25 mg/100 g for potassium for light, medium, and heavy soils, respectively. At medium abundance but at the upper end of the range, the dose of fertiliser should be adapted to nutritional needs. Under conditions of high and very high abundance, nutrient rates, in relation to nutrient needs, can be reduced by 25 and 50%, respectively, without compromising soil fertility and yield. When the abundance is at a low or very low level, fertilisation in excess of the nutrient needs of the plants should be applied to improve the balance of nutrients in the soil. To increase the abundance by 1 mg/100 g, assuming one hectare of soil weighs 3 000 tonnes, an additional 30 kg of the missing nutrient per ha must be applied.

Due to the very low mobility of phosphorus in the soil profile, but also of potassium in medium and heavy soils, basic fertilisation with these nutrients should be carried out in autumn. Cultivation during this period ensures that fertilisers are deeply and evenly mixed throughout the arable layer, a prerequisite for high efficiency.

5.3.3 *Fertilisation with magnesium*

Magnesium is the central component of chlorophyll where photosynthesis takes place. This process determines all vital plant functions from energy metabolism to the synthesis of all kinds of organic compounds. It stimulates the growth of the root system and thus stimulates the uptake of water and other nutrients. Increases nitrogen efficiency and sugar content in the roots. It has a positive effect on overall plant health and resistance to environmental stress.

The nutritional requirements of beet in relation to magnesium per elemental form are greater than those of phosphorus. As a rule, acidic soils are poor in magnesium, and this is mainly due to its high susceptibility to leaching which increases under low reaction conditions. For acidic and low magnesium soils, 30% of the lime dose should be applied in the form of magnesium lime in order to improve the abundance of soil. On magnesium-poor soils, which, however, do not require liming, 60-80 kg MgO/ha should be applied in magnesium-type fertilisers (kieserite) before sowing beet.

5.3.4 *NPKMg fertiliser doses*

Examples of mineral fertiliser doses (kg/ha) under beet depending on the projected root yield, for conditions of average soil content in assimilable phosphorus, potassium and magnesium are given in Table 5. The calculation assumes that the by-products (straw of cereals, oilseed rape and nitrogen-fixing crops) are left in the field and that the accumulated minerals return to the soil. On farms where by-products are harvested from the field, phosphate fertiliser doses should be increased by about 20% while potassium fertiliser doses should be increased by 60-80% compared to the tabulated values.

Table 5. Recommended doses of minerals under beet

Plant	Grain [t/ha]	Doses of minerals [kg/ha]			
		nitrogen (N)	phosphorus (P_2O_5)	potassium (K_2O)	magnesium (MgO)
Sugar beet on manure [30 t/ha]	40	80	–	–	–
	50	90	15	–	15
	60	100	25	–	20
	70	120	35	–	30

Source: http://iung.pl/dpr/publikacje/ZaleceniaNawozowe.pdf [access: [19 June 2025].

5.3.5 *Micronutrients*

Sugar beet has a high demand for micronutrients. It is most sensitive to a deficiency of boron and manganese. Boron deficiency contributes to heart leaf rot and dry root rot. Severe boron deficiency can reduce root yield by up to 50% and sugar content by 3-4%. Problems with manganese availability can occur mainly in sites with high soil pH, especially when the pH exceeds 6.5.

Due to the low mobility of micronutrients in the plant, especially boron, foliar feeding treatments should be staggered and moderate doses applied. The single effective dose of boron is 100 while manganese is 200 g/ha in chelate form or 1.0 kg/ha in sulphate form. The remaining micronutrients should be added to the spraying liquid when there are conditions limiting their availability, e.g. low soil abundance, high reaction, lack of organic fertilisation, insufficient precipitation or improper soil structure.

Usually two foliar feeding treatments are carried out. The first at the stage of 6-8 true leaves while the second 10-14 days later.

The Integrated Production scheme prohibits the use of sewage sludge, post-fermentation products and other sludge of unknown composition for fertilisation purposes due to the specific nature of IP production rules, which are more stringent than those applicable to conventional production.

6. INTEGRATED PROTECTION AGAINST HARMFUL ORGANISMS

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

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

- the use of crop rotation, the appropriate date for sowing and plant density;

- the use of appropriate agrotechnology, including the use of mechanical plant protection;
- appropriate measures and methods of plant protection against pests should be preceded by monitoring of their occurrence and take into account current knowledge on the protection of plants against pests;
- 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 pests.

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 pests;
- limiting the number of treatments and the quantity of plant protection products used to the necessary minimum;
- preventing the formation of resistance of pests to plant protection products by appropriate selection and their alternating use.

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

Plant protection products are to be applied in accordance with the recommendations given on the label and in a manner that prevents hazards to human or animal health or to the environment.

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

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

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. Compliance with the instructions for use, such as, among others, the appropriate choice of the product, the dose, the date of application, the appropriate stages of development of the crop and pests, the appropriate temperature-humidity conditions and the technical conditions for the performance of the treatment, have a decisive influence on the safety of treatments with plant protection products.

6.1. WEED INFESTATION CONTROL

The growth and development of weeds is favoured by cultivation in wide inter-rows and by the slow growth of seedlings during the initial growth period. Both of these factors mean that weed infestation poses a much greater threat to the sugar beet crop compared to its impact on other agricultural crops. During the growing season, crops can be singled out as a period when they are particularly vulnerable to heavy pressure from weeds. For sugar beet, the period of critical competition occurs between germination and 8-9 weeks after plant emergence. Weed infestation occurring at this time has an economically significant impact on sugar beet root yield losses.

6.1.1. Agronomic methods of weed management

An integrated method of weed infestation control

Weed infestation control in an integrated weed control method should not only consist of eliminating the immediate threat but also of using all preventive methods. Integrated weed infestation control methods should adopt the principle of continuous weed control across all crops in the rotation, taking into account recommended methods and environmental protection.

<u>Non-chemical methods of weed reduction</u>

Preventive measures

The weed seed bank in the soil is the main source of weed infestation in arable fields. Any preventive measure that reduces the spread of weeds plays an important role in reducing the potential weed infestation of the soil. These activities include: careful collection of pre-harvest plants (limitation of the occurrence of self-seeding of cereals and rape), keeping machines and tools clean, preventing weeds from the environment to be transferred to arable fields, using fermented manure (hot fermentation).

Crop rotation

Crops grown in rotation are less weedy than in monoculture. An additional benefit of crop rotation is the cultivation of plants with diversified agrotechnical requirements which prevents the compensation of certain weed species and reduces the occurrence of others compared to plants grown in monocultures.

Cultivation of plants with allelopathic properties

The essence of allelopathy is the secretion of specific compounds into the soil environment by plants that modify the growth and development of other plants. It is possible to reduce the abundance of some weeds by cultivating the following as precursor crops for sugar beet: winter rye, fodder radish, buckwheat, white mustard, and blue phacelia grown as catch crops or stubble aftercrops

Agrotechnical treatments

Properly carried out agro-technical treatments (shallow tillage, pre-winter ploughing, pre-sowing cultivation) contribute to reducing the number of seeds in the soil. The time of day when mechanical treatments are carried out is of some importance in reducing seed germination (weed species respond to light radiation). Performing cultivation treatments at night reduces weed infestation in the field during the early growth period of the crop.

Mechanical control

This method continues to be an important tool for weed control and is sometimes the only effective way of controlling weeds, such as beetroot weed, common mallow – (*Malva* *neglecta*), velvetleaf – (*Abutilion theophrasti Medik*) found in crops belonging to classical varieties. Tools that allow mechanical weed control (brush weeders, finger weeders, brush and finger weeders, moustache weeders) are increasingly being used. Much newer solutions are torsion weeders, pneumatic weeders or systems that recognise weeds on a detection basis, allowing weeds to be destroyed close to the crop. Mechanical weed control, in addition to other alternative methods, must be mandatory in integrated production.

6.1.2. Chemical methods of weed infestation control

In integrated plant protection, herbicides are used as a complementary tool for weed control. The main advantage of their use is the rapid elimination of weed infestations and their very high effectiveness. The effectiveness of chemical agents depends on several factors: weed biology, the dynamics of their appearance, the degree of weed infestation, the ability to recognise weed species and their use on individual weed species in the appropriate development stages.

Weed control system

Depending on the beet plantation protection system chosen, herbicides are applied before the crop emerges (non-selective herbicides, acting through the soil) and during the vegetation of the crop by means of split doses or micro-doses. In a split-dose or micro-dose system, the timing of herbicide application is determined by the developmental stage of the weeds and is, for most registered herbicides, independent of the developmental stage of the sugar beet. Although some active herbicide substances show biological efficacy against annual monocotyledonous weeds at the cotyledon stage, in practice there is a need for specific control measures against monocotyledonous species (commonly referred to as graminicides). Graminicides are fully selective at the 2-true-leaf stage of sugar beet – earlier treatment may result in growth inhibition of the beet.

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

Selection of active substances

In the protection of sugar beet against weeds, skilful choice of an active herbicide ingredient adapted to weed species and the development stage of the weeds plays a decisive role.

Combined use of herbicides with adjuvants

The effectiveness of herbicides depends primarily on the species sensitivity and developmental stage of the weeds, the type of active substance, the formulation of the product, the use of adjuvants and the weather conditions. The combined application of herbicides with adjuvants, on the one hand, makes it possible to neutralise adverse biotic and abiotic factors limiting the effectiveness of the treatment while on the other hand, in conditions conducive to their operation, it enables reduction of doses of plant protection products. The use of adjuvants is particularly beneficial in unfavourable weather conditions (periodic water shortages) and in the control of weeds that are moderately sensitive to a particular active herbicide substance. For details on the possibility of using herbicides with adjuvants, refer to the use labels of the individual plant protection products.

Methods of reducing weed resistance to herbicides

The widespread use of herbicides, introduced simplifications in crop rotation and cultivation and mechanical care have contributed to the occurrence of resistant weeds in agricultural crops within a species previously recognised as sensitive to the active substance concerned. The rate and persistence of this process depend on the frequency of application of herbicides belonging to the same chemical groups.
Reducing the risk of weed resistance to herbicides can be achieved by:

- crop rotation,
- limiting the number of treatments with the same herbicide or another with a similar mechanism of action on weeds,
- use of herbicide mixtures with different mechanisms of action,
- application of herbicides to weeds during their period of greatest sensitivity,
- use of herbicides at doses that guarantee complete destruction of weeds,
- in the case of dose reductions, the addition of adjuvants,
- inclusion of mechanical treatments in the weed control system,
- use of non-selective herbicides before crop emergence,
- control of weeds remaining in the field after the chemical method has been applied.

Beetroot weeds

Typical beetroot weeds are characterised by a thin main root from which a large number of lateral roots grow perpendicular to the axis line of the main root. They flower quickly, even as early as the end of June, and their tiny flowers give off a distinctive sweet and honey-like fragrance. Often, red or reddish-purple discolouration can be observed on the stems of the seed shoots, at the leaf angles and at the points of emergence of the lateral shoots. Depending on the weather, the first seeds (which are always multi-seeded clusters) start to ripen as early as the end of July. Sprinkled seeds (up to 9 000 per plant) can remain germinable for several years. In crops of classic varieties, they can only be eliminated mechanically, through manual removal. It is important not to allow seeds to form and fall off. Weeding is best carried out just before inter-row closing (BBCH 39) when beetroot weeds are already clearly visible. At a later stage, seeds must be uprooted and removed from the field.

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

6.2. REDUCTION OF DISEASE VECTORS

6.2.1. Most important diseases in beet cultivation

Beet is a species that is attacked by a range of pathogenic organisms. This is the case in all growing regions of the species worldwide. Some diseases are associated with specific growing regions, some occur almost everywhere with varying severity. Knowing the potential risks to beet is important as all it takes is a confluence of a few unfavourable circumstances and the health of the plants can deteriorate significantly. These include increased humidity and temperature in a given season, varietal sensitivity and phytosanitary defective crop rotation. The severity of pathogens also depends on the area of cultivation and presence of pathogens. The earlier the developmental stage of plant infestation, the greater the losses in the crop caused by the perpetrator of the disease.

The main perpetrators of beetroot diseases are fungus-like oomycetes, fungi as well as bacteria and viruses. The approximate importance of beetroot disease perpetrators is given in Table 6. Diseases such as Cercospora leaf spot of beet, Ramularia leaf spot, powdery mildew, and beet rust are mainly observed in plantations of this crop. In wet and warm summers, seedling blight and root rot occur. Commonly observed symptoms include beet yellows and viral mosaic which are aphid-borne. Bacterial leaf spot can be observed in cool, humid springs.

There are more than a dozen main species of pathogenic organisms that pose a potential threat to the beet crop. If an infection affects the leaves, their assimilation processes are disrupted while their transpiration intensity is increased. Cercospora leaf spot of beet as well as increasingly frequent viral diseases are the main perpetrator of sugar beet losses. As a result of heavy infection by the fungus, the leaves die prematurely and dry out. As a result of the infestation of these parts of plants, there is a decrease in yield and sugar content, and the quantity of molasses creating agents in the root sap increases which leads to greater sugar losses during their processing in sugar factories.

Table 6. Economic importance of beet diseases

Disease (cause)	**Potential threat**
Seedling blight (*Aphanomyces cochlioides*, oomycetes of the family *Pythium*, *Rhizoctonia solani*, *Phoma betae*)	++
Root rot (*Aphanomyces cochlioides*, *Rhizoctonia solani*)	++
Bacterial leaf spot (*Pseudomonas syringae* var. aptata)	+
Cercospora leaf spot of beet (*Cercospora beticola)*	+++
Leaf mould (*Ramularia beticola*)	+
Powdery mildew of beet (*Erysiphe betae*)	+
Beet rust (*Uromyces betae*)	+
Beet yellows virus (BYV)	+++
Beet mild yellowing virus (BMYV)	+
Beet necrotic yellow vein virus (BNYVV)	+

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

6.2.2. Methods for monitoring disease perpetrators in beet cultivation

In integrated plant production, it is important to know both the primary sources of infection, i.e. the places where the pathogen exists as well as the detailed weather conditions that promote the development of the perpetrators of diseases (table 7). The more favourable conditions are for the development and spread of the pathogen, the greater the probability of the occurrence of a given disease and the higher the associated loss of yield. The parts of the plantation adjacent to last year's beet or the places where the roots have been piled in the last two years are areas of particular supervision. When beet is grown after beet, leaf disease (cercospora leaf spot of beet) can occur up to three weeks earlier than would be the case in a normal stand.

Table 7. The most important sources of disease infection and favourable conditions for the development of the pathogens

Disease	**Sources of infection**	**Favourable conditions for development**	
		temperature [°C]	**Soil and air humidity**
Seedling blight	Soil	5–20	High
Root rot	Soil	20–30	High
Cercospora leaf spot of beet	Soil, neighbouring beet fields	15–30	High
Leaf mould	Soil, neighbouring beet fields	15–17	High
Powdery mildew of beet	Soil, neighbouring beet fields	20–30	Low
Beet rust	Soil, neighbouring beet fields	15–20	High
Beet yellows virus (BYV)	Aphids		
Beet mozaic virus	Aphids		
Beet necrotic yellow vein virus	Soil – Polymyxa betae *Polymyxa betae*	Above 20	High

It is first necessary to establish what diseases can be observed in each stage, and then to know the symptoms caused by their pathogens (Table 8). It is important to identify the problem associated with the appearance of disease pathogens on the plantation correctly and as early as possible. Proper diagnosis is an essential step in integrated plant production. Integrated beet production requires systematic monitoring of disease incidence at least once a week after emergence.

Table 8. Diagnostic features of the main beet diseases

Seedling pre-emergence blight	Pathogens infest at the earliest stages of beet development, with damage to sprouts and plants up to the cotyledon stage. The disease is favoured by low temperatures, soil crusting, sowing too deeply, and rainfall. Only *P. aphanidermatum* thrives at higher temperatures, thus its occurrence is also possible at later stages of beet development. The effect of pre-emergence blight is plant attrition. The disease can occur locally. Due to widespread seed treatment, pre-emergence blight is not a significant problem.
Seedling blight	At the grown seedling or young plant stage (1-2 pairs of proper leaves), watery, brownish darkening appears on the hypocotyl (the lowest part of stem) which then blackens. Hypocotyl loses turgor, the seedling ‘folds’ on the soil surface and dries. In the case of infestation of the plant with the first and subsequent pairs of leaves formed, the damaged meristematic cells blacken, there is a characteristic narrowing under the leaf rosette, and the disease symptoms often include the base of the cotyledons. Only the primary vascular bundle remains healthy, which holds the developing leaf rosette until it breaks off due to its own weight. In the event of drought, infested plants dry out. The moment of leaf rosette breaking or drying is considerably delayed in relation to the moment of infection and disease development on a given plant. Occasionally, diseased plants survive and then a distinct constriction is observed in the upper part of the root. The disease usually appears at a time when the protective effect of the fungicides contained in the casing is no longer present. It is favoured by the excessive presence of beet in the crop rotation and soil acidification. Usually, the plant’s early contact with the pathogen may result in the development of root rot in the later stages of beet development (apical rot).
Seedling blight	Hypocotyl of infested seedlings initially browns, then dark-browns, and the infested plant rolls over. Lesions may affect the root or hypocotyl, or may extend to both of these parts of the seedling. Some seedlings present brownish spots on the rootstock. The fungus comes in many forms, only some of which infect the beet. Lesions initially include hypocotyl, then the entire plant darkens and dries.
Brown root rot	Diseased plants are mostly found locally. The first visible symptoms of the disease in the plantation are the loss of turgor by leaves. These symptoms occur on plants heavily damaged by the disease. On the roots, on the other hand, the first lesions are brown discolourations appearing on their lateral surfaces. As it progresses, the disease affects deeper and deeper tissues which blacken. The diseased tissues slightly collapse and crack. As the disease progresses, the head and petiole bases are also damaged and rot. However, the root tip stays healthy the longest. Roots from plantations strongly infested by rot should not be stored for a long time, as they are a source of infection and rotting roots in the primacy.
Root apical rot	Infections caused by *A. cochlioides* occur on the lateral surfaces of the roots, just below the head of the beet, often within the furrow. The infected tissue initially turns brown and darkens as the disease progresses; as the pathogen affects deeper tissues, the damaged surface cracks and decays. Root rot is also repeatedly observed from the apex towards the head. The entire underground part of the root can decay while the part above the soil surface remains undamaged. After digging up, the roots show significant damage to the part in the soil and easily break down.

	In this case, the leaf rosette may lose turgor, turn yellow and dry out or, if there is sufficient moisture in the soil, it may not show any lesions for a long time. When conditions favouring pathogen activity at an early stage of disease development cease, the process can be stopped. In such cases, in the areas of penetration, the pathogen forms a crusted tissue covering the site of the infection, the wounds are healed, and the root surface usually shows corrugation and distortion.
Bacterial leaf spot	Initially, necrosis appears on the margin of the leaf blade. As the disease progresses, symptoms progress deep into the leaf blade along the vascular bundles. Sometimes they cover a large part of the leaf surface and extend up to the main vein. On the surface of the leaf, yellowing and spots of very different shapes appear between the veins, from small, almost circular to large and non-shaped spots. The spots are brownish in colour, sometimes surrounded by a slightly reddish or brown border (a strong resemblance to the spotting caused by whitefly or leaf mould). The tissue inside the spots is moist and appears to be rotting. Leaf blade fragments destroyed by the bacteria later dry out and splinter, leading to changes in leaf shape.
Cercospora leaf spot of beet	The first symptoms of leaf spot of beet appear on the outer whorls of beet leaves. These are brownish-grey, circular spots 0.5-6 mm in diameter (usually 2-5 mm) surrounded by a red, brownish-red, sometimes brownish border. As the disease develops, more and more younger leaves are infested. The spots merge and cause drying of the blade fragments. The resulting necrosis covers the entire surface of the leaf over time. Necrotic spots may also occur on petioles. With prolonged periods of cloudy weather, despite *C. beticola* infesting the leaves, symptom expression and disease development are slowed. In the case of strong infections and lack of protection, there is destruction of foliage which infested plants begin to rebuild intensively. This comes at the expense of increased decomposition of stored sugar in the root which is transported back to the forming leaves. The progressive process of infection and drying of subsequent leaves and the formation of new ones leads to the formation of a characteristic, conical root head. As a result, their weight gain is inhibited, with a simultaneous reduction in sugar content and technological quality of the sap.
Leaf mould	Brownish-grey, irregular spots 4-7 mm in diameter (sometimes up to 15 mm) appear initially on the oldest, and then on subsequent leaf whorls. The development of the disease results in the desiccation of fragments and then entire leaf blades. The frozen tissue inside the spots can crack and splinter. Massively forming conidia within the spots cover their surface with a fine white coating. Diseased plants usually occur in clusters of a few or a dozen.
Powdery mildew of beet	Small white mycelial clusters appear on the leaves. These occur on both the lower and upper surfaces of the leaves. Initially on older whorls, then also on young whorls. The spots merge into greater concentrations and ultimately cover the entire leaf surface. Infected beet plants look as if they have been dusted with flour.
Beet rust	Initially, yellowish spots appear on rust-infected leaves which then swell and take the form of reddish pustules, slightly protruding above the surface of the leaf blade. When ripe, they burst and exude rusty dust – spores, or uredospores.
Beet yellows virus (BYV)	Initially, the leaf blades of diseased beet plants darken and stiffen, then turn yellow from the edges; the process can involve the entire leaf blade. The next stage in the development of virosis is the appearance of brown, necrotic spots on the leaves, after which the process of leaf dieback begins. The stiffness of the leaf blades causes them to crack and crunch characteristically when crushed. This makes it easy to pinpoint beet yellows as the cause of the disease symptoms

Beet mozaic virus	On heart leaves, a brightening of the veins and the appearance of light green surfaces alternating with darker fragments are observed, giving the impression of a mosaic.
Beet necrotic yellow vein virus	Sugar beet infected by the beet necrotic yellow vein virus shows a number of disease symptoms of which the only specific symptom is yellowing of the vascular bundles on the leaf blades and the tissue immediately adjacent to them. Plants infected by beet necrotic yellow vein virus have poorly coloured and sometimes yellowing leaves. This symptom can be mistaken for undernutrition of plants due to a lack of nitrogen in the soil. Diseased plants lose their turgor quickly on sunny days. These symptoms are similar to those observed in the case of root nematode infestation or a potassium deficiency in the soil. The roots of diseased plants develop more slowly and are smaller. At the same time, there is a strong development of lateral roots leading to the formation of a beard similar to that resulting from feeding of the beet cyst eelworm. The vascular bundles are ligneous and darkening is visible on root sections. Such darkening may be the result of root infection by *Fusarium oxysporum* and the effect of certain herbicides introduced into the field as a result of poor rinsing of the spray tank or producer error. The roots of heavily infested plants can decay and rot.

6.2.3. Non-chemical methods of reducing pathogens

In integrated plant protection, several methods are available to limit the occurrence and spread of disease perpetrators and depend on the grower and the specificities of the cultivated species. In the case of beet cultivation, the primary method of reducing the presence of pathogenic organisms is correct crop rotation, but attention should also be paid to other non-chemical methods that reduce the risk of disease perpetrators.

Cultivation method

In practice, this method is implemented by selecting varieties with the greatest possible resistance to infestation by the perpetrators of diseases. The grower, anticipating a potential threat based on knowledge of the pathogens present in the area, should choose a variety with increased resistance to these organisms for cultivation. This reduces the problems associated with the occurrence of diseases. Beet varieties have varying resistance to infestation by individual pathogens.

The correct choice of variety, taking into account resistance to the infestation, allows for more effective chemical protection and better yields.

Agronomic method

In integrated beet production, the agro-technical method is the most important method for reducing the risk from disease perpetrators (Table 9). This method consists of limiting the presence of disease perpetrators by correctly selecting the crop site. Optimising growing conditions reduces the risk of disease. In the absence of alternative control methods, e.g. when chemical methods cannot be carried out due to the lack of registered fungicides, agrotechnological treatments are of particular importance.

The first step in enabling the beet plants to grow and develop properly, and thus be more disease-resistant, is to choose a suitable, nutrient-rich site. Natural crop rotation is one of the most important, and at the same time one of the cheapest agrotechnological measures guaranteeing high and reliable yields, by, among others, reducing the threat from pathogenic fungi. Thus, plant succession should take into account not only agrotechnical but also phytosanitary requirements. The frequent cultivation of beet on a site results in an increased threat from a number of pests. Especially from cercospora leaf spot of beet and root rot. Any fragments left after harvesting should be thoroughly covered. The crop should be located so that, as far as possible, it is not adjacent to other crops of the species or to last year's beet or root stock formation sites.

Adequate nutrient supply, i.e. macro and micronutrients, contributes to increasing the resistance of plants to fungal infestation. Nutritional imbalance increases their susceptibility to both biotic and abiotic stress.

Prolonged emergence, crusted, inadequately rich soil, winds and frosts weaken the plants and make them more susceptible to disease organisms.

Table 9. Key methods of reducing beet disease perpetrators

Disease	Reduction methods
Seedling blight	Correct crop rotation, avoiding root pile sites, early sowing at correct depth, correct soil pH and structure
Brown root rot	Correct crop rotation, avoidance of root pile sites, correct pH and soil structure
Root apical rot	Correct crop rotation, avoidance of root pile sites, correct pH and soil structure
Bacterial leaf spot	None
Cercospora leaf spot of beet	Correct crop rotation, avoiding root crop sites, avoiding proximity to fields of last year's beets, cultivation of varieties with improved resistance (e.g. Cr+)
Leaf mould	Correct crop rotation, avoiding beet-after-beet and root crop sites, avoiding proximity to fields of last year's beet, cultivation of varieties with improved resistance
Powdery mildew of beet	Correct crop rotation, avoiding beet-after-beet and root crop sites, avoiding proximity to fields of last year's beet, cultivation of varieties with improved resistance
Beet rust	Correct crop rotation, avoiding beet-after-beet and beet-root piles, avoiding the vicinity of last year's beet fields
Beet yellows virus (BYV)	Sowing of beets in locations distant from aphid overwintering sites
Beet mozaic virus	Sowing of beets in locations distant from aphid overwintering sites
Beet necrotic yellow vein virus	Sowing resistant varieties

6.2.4. Chemical methods of disease vectors control

Methods for determining the abundance of infested plants and harmfulness thresholds

Accurate and frequent observations of the fields provide a lot of important information necessary for cultivation. This indicates the presence and severity of various pests, including pathogens.

When identifying existing diseases, the time during which these activities are carried out is also important. In the case of sugar beet, if conditions are favourable for the development of pathogens, symptoms can occur very quickly and affect the plants in the plantation to a significant degree. For this reason, frequent monitoring of the foliage condition in the plantation is necessary during periods of danger. The information collected may be used to justify the use of a plant protection product, including a fungicide.

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

6.3. REDUCING LOSSES CAUSED BY PESTS

6.3.1. Main pests of sugar beet cultivation

In recent years, the beet root weevil, beet moth, red spider mite and the black bean aphid have been the main problems in sugar beet cultivation. Spider mites and aphids cause the most damage in dry years. In addition to the above-mentioned pests, the most common pests feeding on beet are grubs and wireworms, pygmy mangold beetle, beat flea beetle, delias, and caterpillars – the cutworms, plusiinae, hadeninae. Occasionally, cassida or beet leaf weevil may appear. As far as nematodes are concerned, the biggest threat comes from the beet cyst eelworm.

It is important to bear in mind that both the species composition and economic importance of pests fluctuate depending on weather, ecological conditions, the cropping system, presence of natural enemies, etc.

6.3.2. Monitoring methods for pests in sugar beet cultivation

Field inspections are essential to correctly estimate the number of pests on a particular plantation and to check whether the harmfulness threshold has been exceeded, which is the basis for a chemical treatment. The most popular methods and tools used for catching and warning about the occurrence of pests are:

- a magnifying glass
- an entomological scoop
- yellow dishes
- colour flypaper boards
- pheromone traps
- a Johnson suction trap
- different types of live traps

Identification of pest abundance is based on soil analyses or observation of whole plants in search of pests or damage caused by them. Integrated beet production requires systematic monitoring of disease incidence at least once a week after emergence of pests.

Soil pests

Soil samples for analysis of beet cyst eelworm abundance should be taken from the depth of the arable layer. It is best to use an auger, or possibly a soil stick. The overall sample must be representative and should consist of a sufficient number of individual samples, distributed systematically over the area to be tested. After thorough mixing of the sampled soil, a total sample of approximately one kilogram is prepared which, properly protected, packaged, and labelled, should be sent to the nematode labelling accredited laboratory as soon as possible.

To assess the abundance of beet root weevil, grubs, wireworms and cutworms, soil from several dozen test pits measuring 25 × 25 cm and 30 cm deep should be excavated and sieved. It is assumed that, in order to obtain representative results from 1 ha, soil samples must be taken from at least 32 locations, and that for each additional hectare, this number should be increased by 2; that is, 2 ha = 34 samples, 3 ha = 36, and so on. Soil sampling points should be distributed evenly across the entire plantation. The number of pests is then calculated.

Foliar pests

The abundance of foliar pests is determined by observing the pests or the damage caused by them, on a few dozen plants in a few randomly selected areas of the plantation, preferably diagonally across the field. The number of inspected plants determines the reliability and representativeness of the results obtained.

Pheromone traps or light traps, the so-called ‘self-catchers’, can also be used to catch the moment of emergence of certain pests.

Pest density is most often given as:

- the average number of eggs or other stages per plant,
- the average number of eggs or other developmental stages per 1 linear metre of a row or 1m^2 of a field,
- number of insects for a certain number of scoopings,
- percentage of plants infested by the pest.

6.3.3. Agronomic methods for the reduction of pests

Methods of pest reduction are shown in Table 10.

Table 10. Pest control methods

Pest	Containment methods and measures
Silver Y	weed control, reduction of butterfly food base (mowing of flowering vegetation on balks), shredding and stubble ploughing of post-harvest residues, soil loosening treatments
Pygmy mangold beetle	early, not too deep sowing, increasing the sowing standard, removing weeds, deep ploughing of post-harvest residues
Wireworms Grubs	choosing the right site, early sowing, increasing the sowing standard, soil loosening treatments, weed control, cultivation of plants hostile to wireworms (beans, peas, mustard)
Beet cyst eelworm	at least four-year crop rotation, ploughing in straw and manure (improves living conditions for parasitic nematode egg-attacking fungi), cultivation of white mustard or oil radish varieties as catch crops (in critical situations in the main crop), cultivation of inert and hostile crops (maize, rye, alfalfa, onions, chicory), control of host weeds, cultivation of tolerant varieties
Black bean aphid	balanced mineral fertilisation, mainly concerning nitrogen and potassium; spatial isolation of the plantation from primary host shrubs (guelder rose, burining-blush, mock-orange); careful control of weeds, mainly

	amaranthaceae
Beat flea beetle	sowing as early as possible, not too deep, control of amaranthaceae weeds, deep ploughing of post-harvest residues, soil loosening treatments
Owlet moths	weed control, reduction of butterfly food base (mowing of flowering vegetation on balks), shredding and stubble ploughing of post-harvest residues, soil loosening treatments
Two-spotted spider mite	spatial isolation from last year's beet crop, ploughing technology
Cutworms	early sowing, increasing the sowing standard, limiting the food base for butterflies (flowering plants on balks), soil loosening treatments, ploughing technology
Beet moth	ploughing technology, pheromone traps
Root flies	sowing as early as possible in a carefully prepared and fertilised site; reduction of adult specimen food base (removal of flowering weeds and vegetation on balks), soil loosening and deep ploughing, weed control
Beet root weevil	sowing seeds as early as possible, increasing the sowing standard, removing weeds, especially amaranthaceae, ploughing technology, trough and pheromone traps

6.3.4. Chemical methods of pest control

Plant protection products should be used in accordance with the list of plant protection products recommended for beet in integrated production (IP). Instructions on the label must be read before application. The messages provided in the Online Pest Warning System (www.agrofagi.com.pl) may be helpful.

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

7. BIOLOGICAL METHODS IN INTEGRATED PROTECTION OF BEET

Biological methods consist of the use of living organisms, such as viruses, bacteria, fungi, nematodes and entomophages (parasitic and predatory insects) to reduce pest populations, disease perpetrators and weeds in plant crops under field and soil conditions. It should be emphasised that biological methods do not control populations like chemical plant protection products do, but only limit populations of pests in the longer term.

Nematodes, particularly the beet cyst eelworm (*Heterodera schachtii*), can be a problem in beet cultivation. In the soil environment, it can be infected by naturally occurring fungi in the soil, including predatory fungi such as: the *Arthrobotrys oligospora* Fresenius species. In addition to predatory fungi in the soil, nematodes are parasitised by other fungal species with a different spectrum of action. These are parasitic nematode fungi, species such as: *Pochonia chlamydosporia*, *Paecilomyces lilacinus* and *Cylindrocarpon destructans*.

In the wild, parasitic fungi under favourable conditions limit populations of many pests, often causing an epizootic episode, or mass extinction. In natural conditions, there are many species of insecticide fungi that reduce the population of plant pests. The *Beauveria* *bassiana* fungus is one of the most common species found on insects. It has been observed on 80 species of insects, mainly beetles and butterflies. It occurs in the soil and in this environment reduces the number of many species of pests wintering there. These include wireworms, whose larvae all develop in the soil, foraging on underground parts of plants. In addition, insecticide fungi can parasitise caterpillars of cutworms overwintering in the soil. In beet cultivation, grubs which are attacked in the soil by different species of insecticidal fungi such as: *B. bassiana*, *B. brongniartii*, *Isaria fumosorosea* and *Meterhizium anisopliae*.

Under favourable conditions (high humidity and temperatures above 20 °C), insecticidal fungi belonging to the entomophthorales (*Entomophthora muscae*) 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. That is why it is so important to carry out treatments that have a beneficial effect on the growth of biodiversity in the natural environment of arable fields.

Insecticidal bacteria such as *Bacillus thuringiensis* are also important in the soil environment.

Biofungicides may contain species of parasitic fungi such as: *Pythium oligandrum*, *Coniothyrium minitans* and *Gliocladium catenulatum* and antagonistic fungi of the genus Trichoderma. These are parasitic fungi that can be found in the soil environment under natural conditions.

In a given growing season, biological measures should be included to protect against plant pests and pathogens. At least one plant protection treatment should be carried out using such products (provided that they are registered for use on the crop in question and that it is necessary).

Plant protection products, including biological products, should be used on crops where they are recommended for use and should follow the instructions on the label for their use.

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

Predatory birds living near plantations are effective in controlling small mammals (rodents, hares). To allow them to watch their surroundings, resting poles of at least 3 m in height should be placed along the plantation (at least 1 unit per 5 ha).

8. PROTECTION OF USEFUL ENTOMOFAUNA IN BEET PLANTATIONS

Protection of bees and other pollinators

When observing beet fields, attention is usually focused on the crop itself and on pests, which include weeds, pathogens and insect pests. Monitoring is aimed at determining the prevalence, size and, as a result, an assessment of the risk of pests, which, if necessary, will help to decide on the necessity of an eradication procedure. It should be remembered, however, that agrocenosis is a habitat of a large number of other species alongside herbivores. Many of them do not play a role in crop production or their impact is insignificant. However, there are also a number of beneficial organisms. Often unnoticed, they can reduce the risk of pests and increase yield. The most numerous and, at the same time, of great importance in crop production are natural enemies of pests and pollinating insects. When observing a beet field, special attention should be paid precisely to these allies and plant protective treatments should be planned in a way that does not endanger them.

Benefiting from the useful activities of these allies is part of the biological method. The second area of this method is the promotion and use of beneficial organisms in agrocenoses. From the point of view of plant protection and biological methods, natural enemies of pests are essential in regulating the prevalence and abundance of harmful insects, and their use should be a very important element in the integrated production of beet.

Another very useful group of organisms are pollinators, bees being the most important among them. The best known are the honey bee (*Apis mellifera*) and the bumble bee (*Bombus* sp.). However, beet is an unattractive plant for pollinators and is therefore randomly and sporadically visited by these species.

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

In view of the obligation to protect crops in accordance with the principles of integrated plant protection, consideration should be given to the selection of plant protection products in order to minimise the negative impact of plant protection treatments on non-target organisms, in particular pollinators and natural enemies of pests.

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

- rational use of chemical plant protection products and basing decisions on the real risk to the beet crop from 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 edges should be considered if the pest does not occur on the whole plantation (e.g. red spider mite). The use of tested mixtures of plant protection products and liquid fertilisers, which reduce entry to 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;
- Dose reduction and adjuvant addition based on the results of analyses.
- constant awareness that protecting natural enemies of beet pests also protects other beneficial species present in the field;
- leaving dead furrow, mid-field refuges for many species of beneficial insects;
- Reading carefully the content of the label accompanying each plant protection product and observing the information contained therein.

> Insects living in the wild within agricultural ecosystems are highly efficient pollinators. In order to ensure conditions for their development, 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 ha.

Protection of biodiversity and beneficial species

The biological method of conservation plays a major role in the cultivation of any agricultural plant. It consists of human modification of the agricultural landscape in order to create suitable conditions for useful organisms in the environment. 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. The use of different cultivation techniques (e.g. non-ploughing) also promotes the development of soil-beneficial microorganisms such as insecticide and nematocide fungi. 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.

Under favourable conditions, insects can appear on the beet to feed on the crop and cause damage. These include aphids, grubs, wireworm, cutworms, and nematodes. Under natural conditions, there are many biological factors that reduce populations of these pests. Within the relationship between the pest and its natural enemy, the following should be mentioned:

- **predation,** where a predator is an organism that kills and eats other species. A predator is usually larger than its prey and usually needs more than one victim for its development. Contact with the victim is usually brief. The victim is killed very quickly.
- **parasitism,** which consists in one individual benefiting from cohabitation, the other suffering from it. An individual who benefits from parasitism is called a parasite, which uses the host's organism continually or periodically as a source of food and habitat, and the one that is harmed is the host. There are two types of parasitism: external, when the parasite spends a certain part of its life on the host (ectoparasite) or inside its body (endoparasite). Parasitoids are distinguished within parasitism.
- **parasitoid –** a parasite whose larvae kill the host and the adults live freely. Most pest parasites are parasitoids.

Ladybirds, both adult insects and their larvae, are of great importance in beet crops under natural field conditions. Ladybirds feed primarily on aphids, but also true bugs, scale insects, mites, fly larvae, as well as young larval stages of butterflies. One ladybird larvae throughout their development (approx. 30 days) can eliminate about 100 to even 2 000 aphids, and the ladybug beetle eats from about 30 to 250 aphids a day.

The most common ladybirds include: seven-spot ladybird (*Coccinella septempunctata* L.), two-spot ladybird (*Adalia bipunctata* L.), fourteen-spot ladybird (*Propylea quatuordecimpunctata* L.).

Representatives of **net-winged insects** (Neuroptera), whose larvae have sickle-like mandibles adapted to hollow out other insects, lead a predatory lifestyle. They feed on aphids. During the growing season, they fly to plants currently affected by these pests. They also eat eggs of other harmful insects and spider mites. 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.

Among the parasites that naturally limit the populations of aphids in beet cultivation are the hymenoptera of the **aphididae** family. Female parasitic wasps lay eggs singly into the body of aphid larvae that are found in the beet crop. The development of the parasitoid larva takes place entirely inside the body of the prey which dies off, and the adult form, after pupating, escapes to the outside through a hole bitten in the dorsal part of the aphid's body. Aphids lose their wax coating, their body becomes matte and transforms into a so-called mummy.

Aphids are also food for predatory flies (Diptera), mainly belonging to **hoverflies** family (Syrphidae). Hoverfly larvae are predators of various species of aphids, and sometimes also of thrips, earwigs and small insect caterpillars. Adult hoverflies feed on pollen and floral nectar, which is a condition for laying an adequate number of eggs. Only the larvae are the predatory stage. They can eat from 200 to 1 000 aphids. An important element in increasing the number of hoverflies in cultivation is to leave enclaves of wild plants or intentionally sowing so-called melliferous plants (phacelia, umbellifers), which provide hoverfly slugs with the necessary food for their development. The agricultural environment affects the occurrence of parasitic and predatory insects. Research carried out at the Field Experimental Station of the Institute of Plant Protection – National Research Institute in Winna Góra showed that most hoverflies were caught on the midfield road. A large number of these individuals have also been recorded in between. Dead furrows were also where the largest number of insecticide fungi were isolated.

In natural conditions, the flies of the family **Tachinidae** play an enormous role in reducing the population of many harmful insects. Parasitisation of many harmful butterfly caterpillars by these Hymenoptera can be as high as 60% in June. Before they begin laying eggs, females feed on pollen and floral nectar from arable and wild-growing plants. Therefore, the presence of flowering plants that lure them close to agricultural land and orchards is of great practical importance for the protection of the beet and provides a food base for this parasitoid.

Of **the heteropterans**, the predatory species represented by the capsid bug (Miridae), minute pirate bug (Anthocoridae), damsel bug (Nabidae) and shield bug (Pentatomidae) families are important. They use their stylets like swords for killing, and then hollow out their victims. They feed on spider mites, aphids, thrips, and the eggs of codling moths and other moths. Within a day, shield bugs can hollow out 50 mite eggs or seven aphid or thrip larvae. Among the Anthocoridae, the common flower bug (*Anthocoris nemorum* L.) plays a major role as a beneficial organism.

The importance of beneficial **Carabidae** beetles is increasing in integrated plant production. They occur in large numbers in all agricultural environments, including beet crops. Due to their large size, high motility and great voraciousness, they are among the most effective beneficial insects, significantly limiting the number of plant pests. Most of them lead a predatory lifestyle by hunting other insects. Ground beetles are typical inhabitants of the surface layers of soil and litter. They usually hunt their victims at night, during the day remaining still under stones, among fallen leaves, and in other shady hideouts. Among predatory ground beetles a phenomenon of food specialisation can be observed. They feed on aphids, ants, caterpillars and butterflies and larvae of various harmful species of beetles and flies. Often, they also feed on snails and earthworms. The smallest of the carabidae, bembidion lampros, feed on the eggs of delias that are beet pests. Ground beetles have huge food requirements. During the day, they eat more food than they weigh.

In natural conditions, **earwigs** (*Dermaptera*) are also included among beneficial insects. They are polyphagous insects. During the day they avoid the light and therefore can be found in various shaded hideouts. Above all, they lead a predatory lifestyle. They limit the number of aphid colonies. They also eat eggs and young larvae of other species of harmful insects, e.g. owlet moths.

Also, beetles from the family of **rove beetles** (Staphylinidae) are among insects that control the number of pests. They hunt both larval and adult forms for various small organisms. The most common species among rove beetles include: Aleochara bilineata (*Aleochora bilineata* Gyll.), Tachyporus hypnorum (*Tachyporus hypnorum* E.) and Philothus fuscipes (*Philothus fuscipes* Mann.). They occur in different environments, but can be found more often on the outskirts of forests and woodlots. Their victims are herbivore species whose stages diapause in the soil. Aleochara bilineata attack larvae, pupa and adult leaf miners and other flies.

Spiders have an underestimated importance in nature. In the fields there are running spiders, large web-building spiders, as well as small spiders, living and building their webs on the surface of the earth and in its crevices. Spiders are non-specialised predators, i.e. their victims are the organisms they are able to catch. However, the vast majority of insects fall victim to spiders, most often those with the highest prevalence in the environment. Because the spider’s diet is dominated by the prey species that is the most numerous at the moment, their importance is greatest during periods of pest infestation of the crops. The role of spiders is then extremely important because they destroy harmful insects in the first period, even before the appearance of other natural enemies of these pests. Often, more insects are caught in a spider's web than a spider can eat. Unfortunately, spiders are polyphagous, so their victims can also be beneficial insects.

The preservation of biodiversity in the natural environment is very important in the proper management of agricultural field pests. Natural enemies are most often unable to continuously control the number of pests to a level below the thresholds of economic damage. However, it should be remembered that integrated cultivation technologies whose basic element is integrated protection against pests, require producers to provide rational protection based on the greatest possible use of useful activity of parasites and predators.

9. PROPER SELECTION OF PLANT PROTECTION TECHNIQUES

Storage of plant protection products

Plant protection products should be stored:

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

b) in a manner ensuring that they:

- are not consumed by or earmarked 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 labelling of plant protection products contain information on the principles of safe storage.

In accordance with the good practice principles, plant protection products should be stored in separate rooms (outside residential and livestock buildings). These rooms must be clearly marked (e.g.: ‘plant protection products’) and protected against unauthorised access, i.e. locked.

If poisoning is suspected in connection with contact with a plant protection product, medical advice must 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, as 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 qualifications to carry out plant protection treatments.

The sprayer operator must be equipped with appropriate protective clothing, as prescribed on the label and in 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 working organisation and available technical measures should be used at each stage of the treatment of plant protection products, in accordance with the principles of <u>Good Plant Protection Practice.</u>

Devices and equipment for protective treatments

The sprayer or other equipment used for crop protection must be in good technical condition, 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 inspection carried out and by the control mark issued by an institution 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 operation that allows accurate dosing and even distribution of plant protection products on the treated area of the field.

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

Calibration (adjustment) of the sprayer

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

The adjustment of the sprayer's operating parameters should be performed when changing the type of chemical agent (especially from herbicide to fungicide or insecticide), the dose of the spray liquid, as well as the setting of operating parameters (working pressure, field beam height). The adjustment of the sprayer is carried out each time when replacing important equipment and components of the sprayer (sprayers, pressure gauge, control device, repair of essential elements of the liquid system), as well as when changing the tractor or tyres of 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 plant protection, selective measures with low risk to pollinators and beneficial organisms must 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 manufacturer's recommendation on the basis of the label, also taking into account the development phase of the 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, the requirements set out on the label of the preparation, i.e.:

- **time intervals between individual treatments;**
- **maximum number of uses of the product during the 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.

Contact-action agents require very good coverage of the plants being sprayed and generally require higher volumes of spray 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 must 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.

<u>Sprayer filling</u>:

- 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 packaging of plant protection products must be rinsed three times, the contents must be poured into the sprayer tank, and the packaging is best returned to the seller;
- 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 with 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. Other components are added to the prepared solution. They must be pre-diluted before being poured 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) and supplemented with 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 ingredients, replenish the tank 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 performed with little wind, rain-free weather and at moderate temperature and insolation. Spraying during inclement weather (strong winds, high temperatures and low humidity) can cause damage to other plants due to spray liquid drift onto untreated areas, and can also cause unintentional poisoning of many beneficial entomofauna species.

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	Limit values (extreme)	Optimal values

		(most favourable)
Temperatures	1–25 °C during treatment	12–20 °C during the treatment
	up to 25 °C on the day after the treatment	20 °C on 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 orchard 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. Distances (buffer zones) from specific sites and facilities for the use of plant protection products are greater on many labels than those indicated above.

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

Post-treatment procedure

At the end of each treatment cycle, removal of the spray liquid from the sprayer should be carried out by spraying the spray liquid in the field or plantation where the treatment was carried out or on the producer’s own unused agricultural area, away from drinking water intakes, and sewer wells. 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 of 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.

<u>Procedure for rinsing the tank and liquid system</u>

- 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.
- Remaining liquid drained from the sprayer should be disposed of using technical devices ensuring biological biodegradation of active substances of plant protection products. Until neutralisation or disposal, liquid residues may be stored in a sealed, labelled and secured container earmarked for that purpose.

<u>External sprayer washing</u>

After the end of the working day, all equipment should be washed on the outside with water, as should its components that have 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 registered biodegradable cleaning agents to enhance cleaning efficiency.

Recording of treatments with plant protection products

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

10. HEALTH AND HYGIENE RULES

During the harvest and preparation for the sale of agricultural produce as part of an integrated plant production system, the producer shall ensure compliance with the following hygiene and health rules:

A. Personal hygiene of workers

1. Persons working in the harvesting and preparation of crops for sale must:
    a. not be infected with or suffer from food-borne diseases;
    b. maintain personal hygiene, observe hygiene rules, and in particular wash their hands frequently 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 that persons involved in harvesting crops and preparing them for sale:

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

b) have undergone hygiene training.

B. Hygiene requirements for crops prepared for sale

The plant producer must take appropriate measures to ensure that:

a. 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.

C. 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 packaging is maintained;
b. order is maintained on driveways and around buildings where merchandise is stored and prepared for trade;
c. farm and domestic animals are not allowed into rooms, vehicles, and packages;
d. harmful organisms (pests and organisms dangerous for humans) which may lead to contamination or pose a threat to human health, e.g. mycotoxins are eliminated;
e. hazardous waste and substances are not stored together with crops prepared for sale.

11. HARVEST AND POST-HARVEST PROCEDURE

Both sowing and harvesting dates affect the length of the beet growing season. This period should be as long as possible, as it contributes in a cost-free way to increased root and sugar yields, thereby improving the profitability of the crop.

CROP HARVESTING

The harvesting of sugar beet roots is done in one stage using six-row harvesters. Removed leaves and root heads are automatically shredded and left in the field as a green manure. At the same time, they must be carefully mixed with soil to limit their role as a primary source of disease in the following crop year. The timing of the harvest depends on the schedule of root deliveries to the sugar factory set by the raw material services. According to the agreement between the producer and the sugar factory, the roots must be stubbed just below the oldest leaf whorl.

Conditions favourable for proper root harvesting are:
– a levelled field surface,
– uniform projection of root heads above the soil surface,
– population of 90-110 000 plants/ha,
– average soil humidity.

There is an alternative method of removing the leaves using what is known as de-leafing. In this case, the head is stripped of its foliage and not cut off. The harvesting date is determined by the cultivation contract. Growers who are scheduled to receive their raw material at the end of November and beyond must dig it up before the frost and snow arrive.

Post-harvest procedure

The root crop harvested with harvesters is collected in a pile. The pile must be located in a place that allows easy access for transport vehicles and loading of the roots with a root cleaner. Shortly before the onset of sub-zero temperatures, the beet should be protected with an non-woven fabric to stabilise the temperature in the pile. Once uncovered, the beet does not clump excessively even at very low temperatures. This offers the opportunity to quickly clean and load the raw material onto transport vehicles and deliver it to the sugar factory.
All root piling requirements are specified in the contracting agreements. The raw material is stored only in piles. The pile should meet the following requirements:
– be close to a paved road,
– be located on a slight hill,
– be piled on looser ground, allowing the beet to be picked up without damage,
– be on a level surface to prevent ponding of water during rainfall,
– be located in a place where there are no trees, poles or other obstructions that impede efficient loading.

The quality of the harvest has a significant impact on beets stored in piles and, consequently, on the profitability of this crop. Damaged or broken beets, and beets with symptoms of root diseases caused by *Rhizoctonia solani*, *Aphanomyces cochlioides*. This is related to the intensive respiration of such roots and the increase in temperature in the pile, which stimulates decay processes. The raw material to be stored should be properly tailed, mechanically undamaged, healthy and with little contamination. The pile should have level side surfaces so that no depressions are formed when it is covered with the non-woven fabric to collect water. In addition, the formed pile must take into account the parameters of the cleaner-loader. This equipment guarantees good pre-cleaning of the beet from excess soil, stones, and other impurities. Transport and loading are handled by specialised service companies.

An obligatory requirement after harvesting beet grown in the integrated production system is to shred the remaining plant residues and mix them with soil.

12. BEET DEVELOPMENT STAGES BASED ON THE BBCH SCALE

Crop development scales are used by plant producers and advisers to precisely define the development phase of a plant, e.g. during treatments and the use of plant protection products. One of the more widely used scales that briefly and transparently describes the phenological development of arable crops is the BBCH scale.

The standard description of the main developmental stages according to the BBCH scale, in the form of a two-digit code indicating the different stages of plant development, is the same for different plant species, regardless of language or country. The first digit identifies the principal growth stage and the second digit is a detail of the advancement in development of the principal stage. Nine main stages of development have been distinguished in beet.

CODE	DESCRIPTION
Principal growth stage 0: Germination	
00	Dry seed
01	Beginning of imbibition: seeds begin to take up water
03	Seed imbibition complete (pellet cracked)
05	Radicle has emerged from seed
7	Shoot emerges from the seed
09	Emergence: shoot emerges through soil surface
Principal growth stage 1: Leaf development (youth stage)	
10	First leaf visible (pinhead-size): cotyledons horizontally unfolded
11	First pair of leaves visible, not yet unfolded (pea-size)
12	2 leaves (first pair of leaves) unfolded
14	4 leaves (2nd pair of leaves) unfolded
15	5 leaves unfolded
1.	Stages continuous till...
19	9 or more leaves have unfolded
Principal growth stage 3: Rosette growth (crop cover)	
31	Beginning of crop cover: leaves cover 10% of ground
32	Leaves cover 20% of ground
33	Leaves cover 30% of ground
34	Leaves cover 40% of ground
35	Leaves cover 50% of ground
36	Leaves cover 60% of ground
37	Leaves cover 70% of ground
38	Leaves cover 80% of ground
39	Crop cover complete: leaves cover 90% of ground
Principal growth stage 4: Development of harvestable vegetative plant parts beet root	
49	Beet root has reached harvestable size

Principal growth stage 5: Inflorescence emergence (second year of growth)

51 Beginning of elongation of main stem
52 Main stem 20 cm long
53 Side shoot buds visible on main stem
54 Side shoots clearly visible on main stem
55 First individual flower buds on side shoots visible
59 First bracts visible; flower buds still closed

Principal growth stage 6: Flowering

60 First flowers open
61 Beginning of flowering: 10 % of flowers open
63 30 % of flowers open
64 40 % of flowers open
65 Full flowering: 50 % of flowers open
67 End of flowering: 70% of flowers open, flowers start to wither
69 End of flowering: all flowers dry, fruit set visible

Principal growth stage 7: Development of fruit

71 Beginning of seed development, seeds visible in infructescence
75 Pericarp green; fruit still mouldable; perisperm milky; colour of seed coat: beige

Principal growth stage 8: Ripening

81 Beginning of ripening: pericarp green-brown, seed coat light brown
85 Pericarp light brown, seed coat reddish brown
87 Pericarp hard, seed coat dark brown
89 Fully ripe: seed coat final colour (specific to variety and species), perisperm hard

Principal growth stage 9: Senescence

92 Beginning of leaf discolouration
93 Most leaves yellowish
95 50% of brownish leaves
97 Leaves dead
99 Harvested product (seeds)

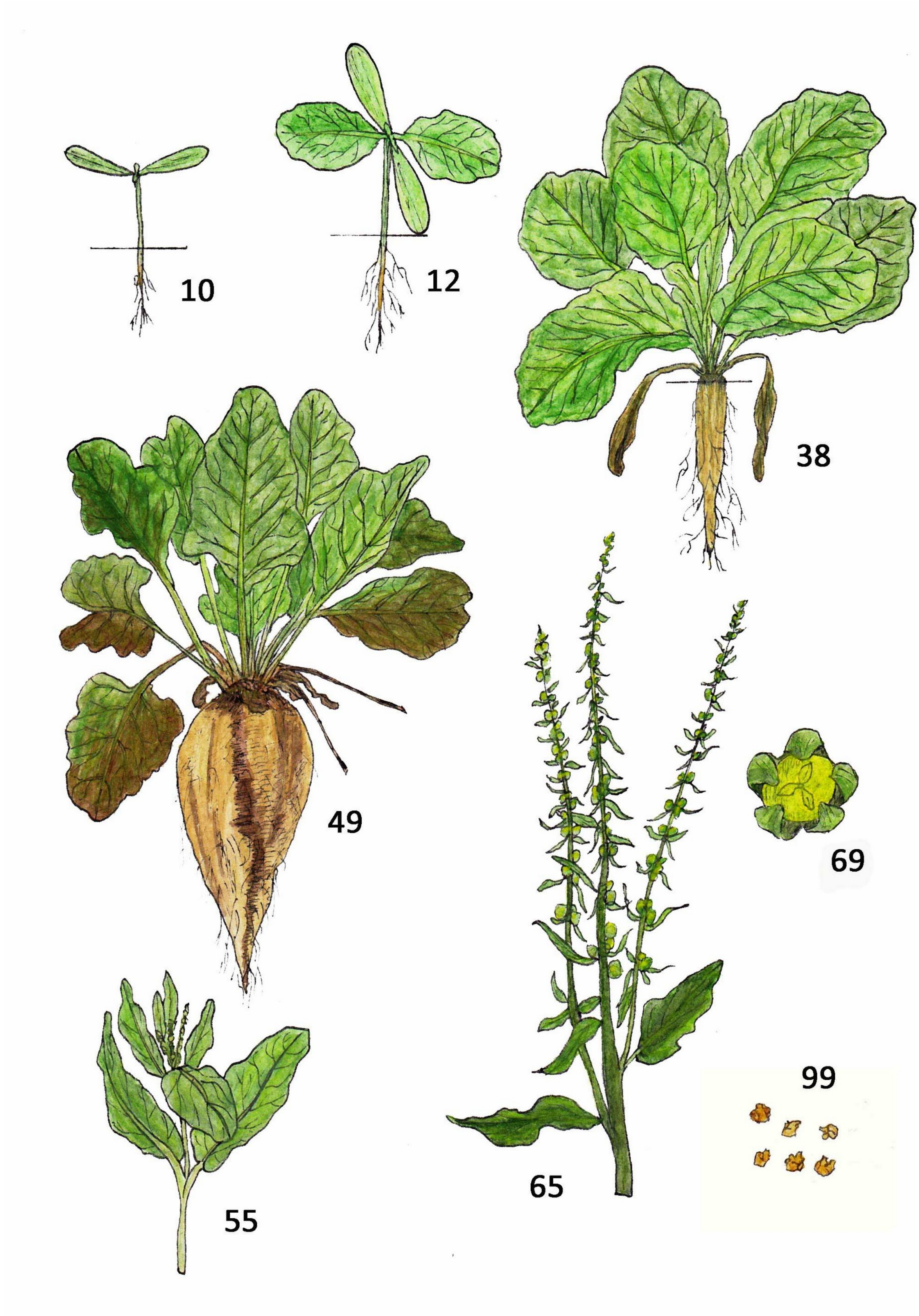

Figure P. Strażyński

13. LIST OF MANDATORY ACTIVITIES AND TREATMENTS IN INTEGRATED PRODUCTION (IP) OF SUGAR BEET

Mandatory requirements (100 % compliance, i.e. 12 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	The use of at least a 3-year break in beet cultivation on the same site (**see Chapter 2.3**).	/	
2.	The use of at least certified seed and sow at the appropriate time and standard (**see Chapter 3**)	/	
3.	Selection of varieties according to the COBORU guidelines (**see Chapter 3**)	/	
4.	Application 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 (**see Chapter 5**)	/	
5.	Soil testing must be carried out at least once every four years by an accredited laboratory (**see Chapter 5**)	/	
6.	Application of a mechanical method of weed reduction (**see Chapter 6.1.1**)	/	
7.	Systematic monitoring from the moment of emergence, at least once a week for disease incidence (seedling blight, root rot, beet leaf spot) (**see Chapter 6.2.2**)	/	
8.	Systematic monitoring from the moment of emergence, at least once a week for incidence of pests (beet aphid, beet flea beetle, beet moth and beet root weevil) using appropriate methods (**see Chapter 6.3.2**)	/	
9.	Performance of at least one pest control treatment with a biological control product (**see Chapter 7**)	/	
10.	Creating the right conditions for the presence of birds of prey, i.e. setting up resting poles at a frequency of least 1 for every 5 ha of IP plantation on the farm (**see Chapter 7**)	/	
11.	Setting up ‘houses’ for mason bees or bumblebee mounds or other facilities for pollinating insects at a frequency of at least 1 for every 5 ha of IP plantation on the farm (**see Chapter 8**)	/	
12.	Shredding and thorough mixing of post-harvest residues (**see Chapter 11**).	/	
	Total points		

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. 27 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	Does the producer produce and protect the crops according to detailed methodologies approved by the Main Inspector?	❑/❑	
2.	Does the manufacturer have up-to-date IP training attested by a certificate?	❑/❑	
3.	Does the producer use only plant protection products from the list of products authorised for IP and for use on the crop in question?	❑/❑	
4.	Are all the documents specified in the methodology and notebook (e.g. test results, proof of purchase) available on the farm and properly stored?	❑/❑	
5.	Is the IP Notebook kept correctly and up to date?	❑/❑	
6.	Does the producer handle empty plant protection product containers and expired products in line with the provisions in force?	❑/❑	
7.	Is chemical protection of crops replaced by alternative methods wherever justified?	❑/❑	
8.	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, counselling on plant protection products or integrated plant production, or any other document confirming the permission to apply plant protection products?	❑/❑	
9.	Is every use of a plant protection product recorded in the IP notebook, taking into account the severity of pest infestation in accordance with the methodology and the need to carry out the treatment?	❑/❑	
10.	Were plant protection treatments carried out under appropriate conditions (optimal temperature, permissible wind speed)?	❑/❑	
11.	Is the rotation of the active substances of plant protection products used in treatments observed?	❑/❑	
12.	Does the producer limit the number of treatments and the amount of crop protection products used to a necessary minimum?	❑/❑	
13.	Does the producer have measuring devices to precisely	❑/❑	

Basic requirements (100% compliance, i.e. 27 points)			
No.	**Control points**	**YES/NO**	**Comment**
	determine the quantity of the measured plant protection product?		
14.	Does the producer comply with the label instructions concerning the preparation of the spray liquid, the disposal of any residues and the cleaning of the equipment?	❑/❑	
15.	Does the producer comply with the label instructions concerning safety precautions for users, staff and bystanders?	❑/❑	
16.	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?	❑/❑	
17.	Are prevention and withdrawal periods observed?	❑/❑	
18.	Are the application rates and the maximum number of treatments during the growing season, as specified on the plant protection product label, being exceeded (if the IP methodology imposes stricter requirements than the label, comply with the provisions of the IP methodology)?	❑/❑	
19.	Were the sprayers listed in the IP notebook in working order and had they undergone a technical inspection (with up-to-date certification) at the time the plant protection products were applied?	❑/❑	
20.	Does the producer carry out systematic calibration of the sprayer(s)?	❑/❑	
21.	Does the producer have a specific place intended for filling and cleaning the sprayers?	❑/❑	
22.	Are plant protection products stored in an appropriately marked closed room in such a way as to prevent contamination of the environment and protect against unauthorised access?	❑/❑	
23.	Are all plant protection products stored exclusively in their original packaging and in such a way that they do not come into contact with food, drink or feed?	❑/❑	
24.	Does the producer apply fertilisation on the basis of the actual nutrient requirements of the crops, determined in particular on the basis of soil or crop analyses?	❑/❑	

Basic requirements (100% compliance, i.e. 27 points)			
No.	**Control points**	**YES/NO**	**Comment**
25.	Is each fertilisation applied recorded in IP notebook in terms of its type, date of application, dose, location and surface?	❑/❑	
26.	Did the producer perform all the necessary agrotechnical procedures in accordance with IP methodology?	❑/❑	
27.	Does the IP producer comply with hygiene and sanitary rules during plant production, in particular those specified in the IP methodology?	❑/❑	
	Total points		

Additional requirements for field agricultural crops (minimum compliance 50 %, i.e. 5 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	Is each box marked according to the entry in the IP notebook?	❑/❑	
2.	Is the recommended catch crop used in cultivation?	❑/❑	
3.	Are fertiliser application machines maintained in good working order?	❑/❑	
4.	Do fertiliser application machines allow for accurate dose adjustment?	❑/❑	
5.	Are fertilisers stored in a separate and specially designated room in a manner that ensures protection of the environment against contamination?	❑/❑	
6.	Does the producer protect empty plant protection product packagings against unauthorised access?	❑/❑	
7.	Does the producer have a dedicated place to collect organic and post-vegetable-sorting residues?	❑/❑	
8.	Are there first-aid kits in the vicinity of workplaces (e.g. storage rooms, utility rooms, cold storage)?	❑/❑	
9.	Does the producer know how to proceed in the event of a spill or the scattering of plant protection products?	❑/❑	
10.	Does the producer use consultancy services?	❑/❑	
	Total points		

Recommendations (min. implementation 20 %, i.e. 2 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	Are soil maps 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 been carried out in terms of nutrient content?	❑/❑	
4.	Is there an irrigation system on the farm that ensures optimal water consumption?	❑/❑	
5.	Is the water used for irrigation tested in a laboratory for microbiological and chemical contamination?	❑/❑	
6.	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?	❑/❑	
7.	Are there instructions on how to deal with spills or scattering of plant protection products on the farm, and are there tools to counteract such a threat?	❑/❑	
8.	Does the producer deepen their knowledge through Integrated Plant Production meetings, courses or conferences?	❑/❑	
9.	Does the producer ensure, in the crop environment, conditions favourable to the survival of natural enemies of harmful organisms (other than those required in the list of mandatory activities and treatments)?	❑/❑	
	Total points		

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