MAIN INSPECTORATE FOR PLANT HEALTH AND SEED INSPECTION

DRAFT

Methodology for the integrated production of maize (*Zea mays* L.)

(fourth edition, revised)

Approved
pursuant to Article 57(2)(2) of the Plant Protection Products Act of 8 March 2013
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by

the Main Inspector for Plant Health and Seed Inspection

Warsaw, 2026

INTEGROWANA PRODUKCJA
URZĘDOWO KONTROLOWANA

Approved by
Magdalena Makowska

/*signed electronically*/

PLANT PROTECTION INSTITUTE — STATE RESEARCH INSTITUTE
ul. Władysława Węgorka 20, 60-318 Poznań
ph. 61 864 90 27, email: upowszechnianie@iorpib.poznan.pl, www.ior.poznan.pl

Collective paper edited by:
Assoc. Prof. Paweł K. Beresia, PhD, Przemysław Strażyński, PhD, Przemysław Kardasz, PhD and Prof. Marek Mrówczyński, PhD

Authors:
Prof. Paweł K. Bereś, PhD, Professor at IOPP-NRI[1]
prof. Marek Mrówczyński, PhD[2]
Prof. Roman Kierzek, PhD, Professor at IOPP-NRIB[2]
Prof. Paweł Węgorek, PhD[2]
Prof. Danuta Sosnowska, PhD[2]
Prof. Marek Korbas, PhD[2]
Prof. Józef Adamczyk, PhD[6]
Prof. Piotr Szulc, PhD[4]
Assoc. Prof. Przemysław Goryński, PhD[2]
Assoc. Prof. Joanna Zamojska, PhD [2]
Roman Warzecha, PhD[6]
Ewa Jajor PhD[2]
Joanna Horoszkiewicz-Janka, PhD[2]
Assoc. Prof. Kinga Matysiak, PhD, Professor at IOPP–NRI[2]
Łukasz Siekaniec, MSc[1]
Ewelina Mazur, Msc[1]
Karolina Piecuch, Msc[5]
Assoc. Prof. Katarzyna Marcinkowska, PhD, Professor at IOR-PIB[2]
Sławomir Drzewiecki, PhD[3]
Assoc. Prof. Krzysztof Krawczyk, PhD[2]
Katarzyna Trzmiel, PhD[2]
Katarzyna Nijak, PhD[2]
Monika Jaskulska, PhD[2]
Jakub Danielewicz, PhD[2]
Marcin Bombrys, Msc[2]

[1]Institute of Plant Protection – National Research Institute, Field Experiment Station, Rzeszów
[2]Institute of Plant Protection – National Research Institute, Poznań
[3]Institute of Plant Protection – National Research Institute, Sośnicowice branch
[4]Poznań University of Life Sciences
[5]Research Centre for Cultivar Testing, Słupia Wielka
[6]Plant Breeding and Acclimatization Institute – National Research Institute

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1. I. PREFACE

Integrated plant protection consists of protecting crops against organisms harmful for plants, 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 harmful organisms (especially about their biology and harmfulness), in order to determine optimal deadlines for taking action to combat these organisms while taking into account naturally occurring beneficial organisms, i.e. predators and parasites of organisms harmful to plants. It also reduces the use of chemical plant protection products (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 harmful organisms. One of the requirements is also to protect beneficial organisms and create favourable conditions for their occurrence, in particular pollinators and natural enemies of the harmful organisms. 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 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.

As much as possible, natural biological mechanisms supported by the rational use of plant protection products are used in the integrated production process. In modern agricultural production technology, the use of fertilisers and plant protection products is necessary. In integrated production, on the other hand, particular attention is paid to reducing the role of chemical crop protection products used to limit pests to a level that does not threaten crops, fertilisers and other necessary products needed for crop growth and development, so that they create a system that is safe for the environment, while ensuring high-quality yields, free of residues of substances considered harmful (heavy metals, nitrates and crop protection products).

More information on the integrated plant production system application 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

Maize is a thermophilic crop, hence it is one of the latest spring crops to be sown. The optimum temperature for germination is 10–12 °C, whilst the optimum temperature for growth and development is 20–30 °C. Temperatures falling below 0 °C cause damage to the plants, which is why maize is particularly sensitive to spring and autumn frosts. The water requirements of maize are high, especially in the phases of intensive growth, flowering and pollination. The highest yield losses occur with rainfall shortages during flowering, when water stress reduces pollination and grain formation. The average annual rainfall requirement is 500–700 mm, and it is crucial that it is evenly distributed throughout the growing season. The length of the growing season and the sum of effective temperatures determine whether particular varieties can be grown. In temperate climates, varieties with a shorter growing season, which are better adapted to local temperature and water conditions, are preferred.

2.2 Soil

Maize is a plant with moderate soil requirements, but it should not be sown in the most inferior sites. The best soils are those on very good and good wheat complex soils, but these are usually used to grow other crops with stricter requirements. Due to the increasing area under maize cultivation, it is being sown on a variety of sites, so it is necessary to gradually improve the quality of such soils and conditions for plant development, if only through care measures. For maize, the best soils are those with a well-developed humus level, airy, preferably with clay in the subsoil.

It is recommended that the soil intended for maize cultivation should have a regulated pH between 5.5 and 7.2 as only such conditions ensure optimal growth conditions and a good supply of minerals. The right soil pH allows the plants to build a large root system which enables them to take up nutrients and water from deeper in the profile, increasing the drought tolerance of the field. In an acidic environment, even very high mineral fertilisation does not secure the nutritional needs of maize as the plant is unable to effectively take up nutrients from the soil. In addition, soil microorganisms that are responsible for the mineralisation of manure, liquid manure or straw thrive very poorly in acidic soil.

2.3 Precursor crops

Maize is classed as a fodder crop the cultivation of which does not require mandatory crop rotation. However, it should be remembered that this species in crop rotation, even simplified, yields 10–20 % and sometimes 30 % better than in monoculture. Crop rotation plays an important role in maintaining better plant health. Monoculture is a significant factor in increasing the threat from some diseases and pests, including Western maize smut, European maize borer, wireworms, grubs, maize smut, head smut of maize, and fusarium diseases. Some species overwinter in maize residues, some have a multi-year development cycle, and others have survival stages that remain viable for up to several years.

<u>Very good precursor crops</u>: root crops: sugar beet and fodder beet; tuber crops: medium-early and late potatoes, as well as industrial potatoes; legumes: edible and fodder peas, white and narrow-leaved lupins, field beans, vetch; vegetables: carrots, parsley, parsnips, celery, leeks, open-field cucumbers, open-field tomatoes.

Suitable precursor crops: all species of winter and spring cereals; legumes: yellow lupin; tuberous root crops: early potatoes and seed potatoes – provided that measures are taken to prevent water and wind erosion; mixtures of legumes with grasses or cereals.

Bad precursor crops: maize cultivated for grain and silage, sweetcorn, sorghum, Jerusalem artichokes.

In the maize IP, maize may be grown following a previous maize crop – provided that no Fusarium diseases or increased pressure from the European maize borer were detected in the previous season.

3. SELECTION OF MAIZE VARIETIES IN INTEGRATED PRODUCTION

Grain and silage varieties, depending on their length of vegetation, are allocated to three earliness groups: early, mid-early and mid-late as expressed by the FAO number. The regionalisation of maize varieties with regard to earliness of ripening is very important as sowing varieties that are too late may result in an inability to achieve the required parameters (yield and earliness), and sometimes in the impossibility of harvesting the crop. Greater restrictions refer to varieties for grain than those for silage.

Breeding type is another criterion for characterising maize varieties. Among registered maize varieties, the main breeding types are single hybrids, i.e. two-line hybrids (SC), consisting of two lines (A×B), and three-line hybrids (TC), consisting of three lines, i.e. (AB) × C. Double hybrids, i.e. four-line hybrids (DC), are the product of crossing two (AB) × (CD) single hybrids.

Maize is grown primarily to produce two usable products: grain or a general yield of plant dry matter with the highest possible proportion of cobs. The importance of an abundant cob yield decreases for varieties bred to obtain a high digestible matter contained in the vegetative fraction of the plant. The modification of fodder grain utilisation is silage from maize cob mix (CCM).

Another issue is the non-fodder use of the grain, e.g. for technical ethanol production (in which case the earliness of ripening may be less important) and the use of the organic matter of the plants for energy purposes (technical ethanol or biogas production is permitted under IP), in which case the proportion of cob yield is not so important.

The optimal grain variety should be characterised by:

- the ability to create large grain yields in areas where such production is possible,
- adequate earliness, i.e. the ability to develop at lower temperatures and to ripen and dry the grain in the field with persistent green leaves (‘stay green’) before the planned harvest date,
- generative plant type (not too tall stems without any tendency to tillering), with low susceptibility to pests and diseases (especially European maize borer and fusarium diseases), with high resistance to lodging,
- in the case of maize cultivation for the milling industry, the grain should be of the glassy type (flint), crumbling into small fragments during processing, and of the floury type, mostly tooth-shaped (dent), for starch production and fermentation,
- as little susceptibility as possible to stress conditions, especially periodic water shortages.

In silage varieties, preference is given to:

- high overall yield of dry matter with a favourable structure, i.e. a high proportion of cobs and high energy concentration,
- earliness appropriate to the intended harvest date: under average weather, silage ripeness of early varieties is already at the beginning of September or even the end of August, and of later, more prolific varieties at the end of September,
- high digestibility of vegetative parts of plants. This trait is of great interest to maize breeders. The matter of stems and leaves with higher digestibility is used more efficiently by cattle. In this respect, there are quite significant differences between varieties; some breeding programmes are already developing varieties with improved digestibility of the plant's cellulose fraction. In such varieties, the high proportion of cobs in the yield structure is somewhat less important.
- varieties with higher stem and leaf digestibility would also be more suitable for biogas production. The primary criterion for the suitability of varieties for biogas plants is the highest possible total dry matter yield. This condition can be met by relatively late varieties that form a large vegetative mass and make good use of the whole vegetation season.

As universal criteria for the selection of varieties for cultivation, the response to cold weather and unfavourable phenomena in the early growth stage should also be taken into account. Important features of grain and silage varieties are also their greater tolerance to certain pests, e.g. the European maize borer, and diseases, e.g. maize cob fusariosis and root rot, and basal stem rot.

Only certified material must be used for the establishment of maize plantations. The cultivated variety must be on the list of varieties recommended for integrated production. This list is maintained by COBORU. Plantations managed under the integrated production system may also be established using varieties listed in the CCA catalogue, provided that the choice is justified in line with the objectives of IP (the variety must be resistant to a biotic or abiotic factor).

The use of organic heterogeneous maize seed material is prohibited for the establishment of plantations in the IP.

Organic heterogeneous seed is not certified seed and is characterised by a high degree of genetic and phenotypic diversity amongst individual propagating units (these are not varieties and are not subject to official testing). When selecting the appropriate variety in accordance with current guidelines, one should take into account the maturity of the crop by choosing the appropriate FAO rating, as well as the intended use (grain or silage), where grain yield is important, but so too is the digestibility of the fibre in the case of silage. Given the restrictions on the use of pesticides, varieties should exhibit increased tolerance to certain pathogens, as well as to stressful conditions (periodic water shortages and fluctuating temperatures, e.g. temperatures that are too low during germination). Organic heterogeneous material is not able to provide these characteristics as it is characterised by a very high degree of genetic diversity and is not homogeneous/repeatable.

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

4. PRE-SOWING TILLAGE AND SOWING

The task of tillage is to create good conditions for uniform emergence and for the growth and development of maize plants, by improving soil water-air relations, reducing the amount of weeds and self-sowing of the precursor crop plant, enabling crop residues and mineral fertilisers to be mixed into the soil without reducing the activity of beneficial soil microorganisms. Tillage should be carefully carried out to prepare the conditions for optimal plant development.

4.1 Soil cultivation

One of the most important tasks of tillage for maize is protection of water in the soil. The plant is very economical, using 358 litres of water to produce 1 kg of dry matter, compared to 507 litres for wheat and as much as 859 litres for alfalfa. Despite its economical management, the species uses huge amounts of water reaching several or even several million litres from an area of 1 hectare. The late sowing date means that in some cultivation regions, drought stresses occur already in May. Water should therefore already be collected and conserved during autumn and winter treatments. Post-harvest cultivation should be considered as a basic treatment which, if carried out immediately after harvesting the precursor crop, interrupts the unproductive evaporation of water from the soil. Retention of water depends on the physical properties of soil which cannot be changed but also very much on the organic matter content of the soil. It also determines the value of the soil's sorption complex, its fertility and is a source of nutrients for microorganisms and subsequently for crops.

Classical maize cultivation presupposes winter ploughing, but the species tolerates any simplification well, including shallow ploughing which reduces the effort involved. When catch crops are used, ploughing is carried out in spring, early enough so that the soil has time to decompose and does not dry out before sowing the seed. If weather conditions shorten the spring field preparation period for sowing, it becomes necessary to compact the soil by rolling, otherwise crop emergence is uneven. Cultivation, after an autumn ploughing leaving the soil in deep furrows, starts in spring by ploughing the soil with a volok which generally takes place on waterlogged soils. Subsequently, or as the primary spring treatment, a pre-sowing unit consisting of a cultivator with rigid arms and an open-cage roller is used. Spring cultivation of the field should be shallow, not deeper than 4–5 cm. The aim is to minimise soil drying out as much as possible, ensuring that the seeds can draw water from below through unbroken capillary channels and that they have access to air from above. Such conditions favour uniform plant emergence.

The wide inter-rows, imposed by the construction of harvesters, encourage water and wind erosion, which, with the high proportion of maize in the sowing structure, can lead to degradation and a reduction in soil fertility. Introducing simplified cultivation up to the stage of preparing the seedbed with other deep loosening tools reduces or even eliminates this problem.

Strip till is becoming popular to reduce erosion, allowing the plant's requirements to be reconciled with soil, water and air protection orders. Limiting the width of the cultivated strip to less than half the width of the inter-row significantly reduces costs while leaving the inter-row completely intact. Research into this technology has confirmed its usefulness. An additional benefit in strip cropping is that the number of weeds in the field is significantly reduced.

When growing maize under the integrated production system, direct sowing is prohibited.

4.2. Sowing maize

Maize seed should only be purchased in its original, sealed packaging, bearing a seed label.

Sowing time

Like other species from the tropical zone, maize is a short-day plant with C4-type photosynthesis. This species is distinguished by a strong photoperiodic response, hence the choice of sowing date is of great importance for plant development and yield. Early sowing usually leads to higher seed yields. It is best to start sowing when dandelions and bird cherry trees begin to flower. In the event of a hard frost in spring, all emerged plants die, regardless of their developmental stage. A short frost destroys the first leaves, but the plant quickly regenerates from the underground part of the stem where the apical meristem is hidden when favourable thermal conditions arrive. Maize plants undergo hypothermia at 0–5 °C. If such a condition is prolonged over time, dieback may then occur. Maize is usually sown when the soil at a depth of 10 cm reaches a temperature of 8–1 °C [sic]. Early varieties show greater tolerance to delayed sowing.

Plant density, row spacing, sowing depth

Due to the changing weather conditions in the IP, it is allowed to delay the sowing date by 7 days in relation to the optimal dates for individual cultivation areas.

Maize should be sown at a depth of 4–5 cm. Deeper sowing provides better moisture, but the temperature of the soil around the caryopsis is then lower, resulting in a slower uptake of nutrients. However, in the case of significant drying of the top layer of soil and no forecast of imminent rainfall, deeper sowing of up to 7–8 cm is allowed on lighter soils.

Planting density should depend on the variety sown and follow the recommendations of the breeding and seed companies. Usually, when growing grain varieties, the plant density is 70–80 000 kernels/ha. For the cultivation of silage maize, sowing at a higher stocking density is permitted. However, in high-energy silage production, plant density should be similar to that used in grain technology as the primary aim is to achieve a high proportion of grain in the whole-crop yield. The row spacing is usually 75 cm which allows the crop to be harvested more easily later with a harvester.

The uniformity of sowing and the right plant stand are guaranteed only by precision seed drills. The number of seeds actually sown by the seed drill should always be checked before starting work in the field.

In cultivation areas where there are repeated periods of drought, especially in fields with light soils, it is advisable, irrespective of the earliness of the variety, to use a reduced sowing density of 7 plants/m^2. In contrast, with good access to water, grain yield stabilises at a density of 8 plants/m^2. On better soils, slightly more plants per unit area can find favourable conditions for growth and yield.

5. SUSTAINABLE MAIZE 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 at an accredited laboratory (and confirmed by documents).

Proper fertilisation of maize must take into account the effectiveness of the fertilisers and the environmental effects of the application. Consequently, good agricultural practice requires the agricultural producer to follow specific rules on how and when to apply them. This is the only way to achieve a high yield of good quality at relatively low production costs. The basis for action is always to know the nutrient abundance of the soil by analysing soil samples.

Maize is a crop with high nutritional requirements that far exceed those of other cereal crops. The high level of inputs required as a result is why maize is classed as an intensive crop. Therefore, high yields and, at the same time, good crop quality are only possible with a correctly balanced nutrient supply throughout the vegetation season. Maize grown for grain requires, to produce 1 tonne of dry matter (grain and straw), approximately 20–32 kg N; 8–10 kg P_2O_5; 22–32 kg K_2O; 4–6 kg Mg; 4–5 kg Ca and approximately 4 kg S. In turn, maize grown for silage, calculated per 1 tonne of green matter in the above-ground parts, must take up from the soil approximately 3.5–4.1 kg N; 1.3–1.5 kg P_2O_5; 6.3–7.7 kg K_2O and 0.7–0.9 kg MgO.

Nitrogen

The nutritional requirements of maize increase as the vegetation season progresses, particularly with regard to nitrogen, most of which is taken up during flowering. Maize, as one of the few species able to assimilate carbon via the C_4 track pathway, requires not only warmth but also a good supply of nutrients with suitable soil pH (6-7.2). The following assumptions should be made before developing nitrogen fertilisation technology for maize:

- conditions must be created for optimum action of the component in the nitrogen fertiliser applied,
- nitrogen should be applied at the maximum dose for production purposes, but, at the same time, at the minimum dose to meet environmental objectives (integrated cultivation, eutrophication of natural environment).

The basis for achieving a high maize yield is the growth conditions of the plants at the stage of 5-6 leaf development when the primary grain yield structure is formed. The second critical stage for the nitrogen requirement of maize is from the 6-7 leaf stage to the full tassel formation stage. The most precise way to calculate the amount of nitrogen applied under maize is to make a balance sheet for this nutrient. This method takes into account the quality and type of soil, the mineralisation of organic matter from crop residues (type of precursor crop), the organic fertilisers applied and the need for liming. However, a far better method of determining soil mineral nitrogen abundance is to conduct the N_{min} test. It consists in determination of two forms of nitrogen in spring: NO_3 (nitrate form) and NH_4 (ammonium form) in a 60 cm soil profile. Knowing the amount of mineral nitrogen in the soil and the unit requirement of maize in relation to this nutrient makes it is possible to proceed to calculating the nitrogen dose. However, under IP, the test is not required.

Due to the peculiar dynamics of nitrogen uptake by maize, the nitrogen dose should be divided and applied at two times. The first, pre-sowing part of the dose should be around 60-70% of the total maize requirement for this nutrient. If the soil is light, with a poor sorption complex, then the dose should be reduced. The remainder of the nitrogen should be applied between emergence and the 6-7 leaf stage. Application of only one dose of nitrogen, traditionally sown before sowing maize, should only be done on heavy or medium soils. Single-dose pre-sowing fertilisation should be carried out with slower-acting nitrogen fertilisers (urea, ammonium sulphate) about 2 weeks before sowing maize.

A very important issue when developing nitrogen fertilisation technology for maize is to identify the genetic profile of the variety selected for cultivation. The classical model of nitrogen uptake by maize is that plants accumulate 85-100% of the required nutrient during the vegetative growth stage, while during the grain dressing stage, there is a process of displacement of organic nitrogen compounds from the resources accumulated during the vegetative growth stage and little uptake from soil resources. This applies only to classic varieties that are not green almost to the end of the vegetation season (the so-called 'stay-green' type).

Phosphorus

Phosphorus has important functions in plant life processes such as photosynthesis and respiration. When fertilised correctly with phosphorus, plants achieve a higher efficiency of the photosynthetic process and manage water more efficiently. This macronutrient is taken up by maize from the soil from the very beginning of the vegetation season, because 2 weeks after germination, the phosphorus reserves in the grain are exhausted. As the vegetation season progresses, uptake increases and continues until full grain ripeness (grain flooding). The critical stages of need for this nutrient occur from germination to the 6–8 leaf stage and at ripeness.

Available phosphate superphosphate fertilisers can be used under maize while magnesium superphosphate can be used on lighter soils. At the same time, it should be remembered that one way to increase the availability of phosphorus for maize is to maintain a soil pH between slightly acidic and neutral. In terms of such soil reaction, phosphorus is most readily available to the plant and then the type of phosphorus fertiliser no longer plays such an important role.

Potassium

Potassium is taken up intensively by maize from the 5-6 leaf stage until flowering, after which the need for this nutrient gradually decreases. Sufficiently high soil potassium abundance allows maize to manage water efficiently which has an impact on flowering and caryopsis setting, and increases resistance to disease and unfavourable habitat conditions. A potassium deficiency is manifested in inhibited plant growth, an unnatural dark green colouring of the leaves, formation of necrotic spots on leaf margins, poor grain filling, and an increased tendency to lodge, especially with intensive nitrogen fertilisation. Knowing the soil's abundance, nutrient requirements, the size of the expected yield, and its intended use enables full balancing of maize nutrient needs in relation to this component. Among pre-sowing potassium fertilisers, potassium sulphate or high potassium salts are the best. Potassium fertilisers in maize cultivation are best sown once as part of pre-sowing, during the period when the soil is being prepared for sowing.

Magnesium

Maize takes up from 30 up to 70-80 kg MgO/ha in a year. Symptoms of magnesium deficiency in young plants are the formation of light discolouration along the leaf veins and, later on, disruption of flowering and pollination which reduces cob setting and worsens graining. The critical period in terms of Mg requirement comes during grain setting and maturation. The choice of magnesium fertiliser depends on the soil reaction as well as the abundance of this nutrient in the soil. Acidic soils are treated with calcium and magnesium fertilisers. Soils with regulated pH but low Mg abundance — with magnesium sulphate fertilisers. On the other hand, on soils with a regulated pH and average Mg abundance, magnesium fertiliser is applied with a base fertilisation of NPK + Mg. The magnesium requirement of maize can be met, e.g. with kieserite, kainite and magnesium-containing calcium fertilisers such as dolomite, magnesium oxide lime, magnesium carbonate lime (soil deacidification + magnesium supplement). The optimum time to apply magnesium fertiliser is in autumn under pre-winter ploughing. Magnesium in maize cultivation can also be applied in a foliar manner. This method of applying the ingredient is one of the most effective as in the event of a deficiency in the plant, symptoms of deficiency can be remedied very easily. Foliar application of magnesium is recommended at two critical growth stages: at the 5-8 leaf stage and in the post-flowering period until full ripeness.

Calcium

Calcium is a nutrient found in the soil in sufficient quantities for maize. Deficiency can only occur with high NPK mineral fertilisation which is manifested as curling and sticking of leaves. However, it should be remembered that field liming is a treatment that improves soil structure, increases soil microbial activity and enhances nutrient availability (e.g. phosphorus availability in a slightly acidic and neutral pH). The application of lime fertiliser under maize in autumn or spring is necessary if the soil pH is below 5.5. The dose and form of lime under maize is determined by the need for liming as well as the agronomic category of the soil. In crop rotation with maize, it is best to apply calcium fertiliser after harvesting the precursor crop as the long period between harvesting and sowing the maize allows the soil to reach the correct reaction.

Sulphur

Sulphur is an important nutrient, essential for proper plant growth and development. The decline in sulphur dioxide emissions in recent years, high crop yields and the use of fertilisers deprived of this nutrient for a prolonged period in most cultivation regions have worsened the supply of this nutrient to plants. With sulphur deficiency, the protein content of the plant decreases, a clear symptom of which is inhibited growth. Moreover, sulphur deficiency leads to a reduction in the efficiency and use of nitrogen from nitrogen fertilisers. Each missing kilogram of sulphur per hectare means that an average of approximately 15 kg of the nitrogen applied is not being used by the crop. When determining the amount of sulphur, account should be taken of the abundance of soil and the needs for this component. Sulphur fertilisation is particularly important when applying high doses of nitrogen as this macronutrient influences not only yield increases but also nitrogen use. Sulphur deficiency in the soil can be remedied by applying fertilisers containing sulphur as a by-product, e.g. ammonium sulphate, potassium sulphate, simple superphosphate.

6. INTEGRATED PROTECTION AGAINST HARMFUL ORGANISMS

Integrated production (IP) of maize should be carried out using integrated pest management 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 agronomic technics, including the use of mechanical plant protection;
- the adoption of appropriate measures and methods for the protection of plants against harmful organisms should be preceded by the monitoring of their presence and take into account current knowledge on the protection of plants against them;
- use of seed produced and assessed in accordance with seed legislation;
- the use of resistant and tolerant varieties (where possible);
- the application of fertilisation and liming, where appropriate;
- the use of hygiene measures (cleaning, disinfection) to prevent the occurrence and spread of harmful organisms;
- the protection of beneficial organisms and creating favourable conditions for their occurrence, in particular for pollinators and natural enemies of harmful organisms.

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

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

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

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 and to the environment.

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

For protection against harmful organisms (weeds, disease vectors, pests), only products registered and authorised for marketing and use may be used if they are clearly identified on the labels attached to the packaging as recommended for use in maize cultivation.

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

6.1. Weed infestation control

Weeds are an integral part of agricultural fields and their diasporas (seeds, rhizomes, adventitious roots, bulbs) in the soil are the main cause of weed infestation. We speak of weed infestation when weeds occur in quantities or in biomass directly or indirectly leading to economic losses. Economic losses as a result of a weed infestation may result from a decrease in the quality or quantity of yield, a depletion of value or an increase in labour intensity and energy intensity of production.

Weeds and the associated risk of weed infestation depend on habitat conditions and the rhythm of crop development. As a permanent element of arable fields, weeds utilise habitat conditions efficiently. This is due to their survival strategies, physiology and life cycle, and their ability to compete for water, light and nutrients.

The amount of crop losses as a result of weed infestation depends on the botanical composition of weeds and the period during which infestation occurs. Which species and in what number appear in the field depends, among others, on the abundance of weed diasporas in the soil, soil and climatic conditions, tillage, and especially care treatments. Hence, the botanical composition of weed infestation in different regions of the country and even within adjacent fields can vary significantly.

Maize is the crop sown latest among the country's spring crops. The advantage of this timing is that the site can be prepared (autumn ploughing, harrowing, cultivator) when there are relatively many weeds on the site. Diligent cultivation contributes to their destruction. The remaining features of maize crop favour heavy weed infestation. The key factors include: wide row spacing, generally 70 cm, and sparse sowing within the rows, at a rate of 8–10 plants / m^2, as well as a long emergence period due to a sowing depth of approximately 5 cm. Typically, the vertical growth of a plant with a narrow cross-section that does not branch provides minimal competition for weeds, particularly during the early stages of development. Regardless of the environmental conditions, for at least a month or so after sowing, the surface of the maize field remains available to weeds and is almost completely free of crop competition. If there is warming combined with rainfall during this time, there is very rapid weed growth. As can be seen from an analysis of the factors accompanying the initial growth of maize, whatever they may be – they always favour weed infestation.

6.1.1. The most important weed species

Overall, there are more than 100 weed species in maize crops, but about 40 are common. Their intensity is related to the so-called 'seed bank', i.e. the seed stock in the soil which depends primarily on the weeds present in the precursor crops as well as environmental conditions. These include soil type, acidity, water content, fertility, and soil temperature. Cultivation is an additional element. In traditional methods taking crop rotation into account, there are a few to a dozen annual monocotyledonous and dicotyledonous species in the fields. Greater weed biodiversity can be observed on plantations managed as monocultures (permitted in maize IP in justified cases). Such sites become habitats for Panicoideae weeds (barnyard grass, crabgrass, bristle grasses) and red-root amaranth. In contrast, perennial weeds appear in fields under various types of simplified tillage.

The most common weed species in maize are: small-flowered crane's-bill, common mugwort, maizeflower, cockspur, common fumitory, small bugloss, field pansy, field mustard, chickweed, common stork's-bill, purple dead-nettle, common henbit, Lamb's quarters, common poppy, false mayweed, creeping thistle, hairy crabgrass, common purslane, couch grass, field bindweed, common hemp-nettle, speedwells, cleavers, European black nightshade, wild buckwheat, spotted lady's thumb, pale persicaria, common knotgrass, chamomile, wild radish, flixweed, red-root amaranth, shepherd’s purse, field pennycress, yellow foxtail, velvetleaf, and potato weed.

6.1.2. Agronomic methods of weed management

Weed control by mechanical methods ideally starts with post-harvest cultivation carried out immediately after harvesting the precursor crop. One of the methods is shallow tillage at a depth of 5–7 cm as it then reduces soil moisture loss, destroys existing weeds, and stimulates further seeds to germinate. To prevent water loss, the field should be harrowed as soon as possible. Another way to carry out post-harvest cultivation is to use a disc harrow or a stubble cultivator. After using these tools, the crop residues will be thoroughly mixed with the soil and the weed seeds stimulated to germinate. Once the weeds have germinated, they should be thoroughly and systematically controlled through a series of cultivation measures. Seeds of spring crops, after germination and emergence, die when sub-zero temperatures occur and, moved deep into the soil, emerge in spring. In spring, when moisture and soil conditions allow the entry of equipment without the threat of destruction of the soil structure, one should begin harrowing. This treatment reduces evaporation which results in faster warming of the soil and more seeds being stimulated to germinate. Subsequent harrowing or the use of a cultivator, volok or a cultivation machine destroys the emerging weeds. There is relatively plenty of time for spring soil preparation as maize is one of the latest crops to be sown.

Maize should first be weeded mechanically; if further action is required, limited chemical control may be used. The mechanical method uses different types of weeder or a weeder with passive or active working elements to remove weeds from between the rows.

Due to the uneven emergence and differing developmental stages of the weeds, it is often necessary to carry out at least two mechanical weeding operations during the course of treatment to achieve a satisfactory herbicidal effect, e.g. at the 2-3 leaf stage and 5-7 leaf stage of maize. This method is not entirely effective as it is difficult to remove weeds in the rows and in their immediate vicinity. Removing advanced weeds can damage the root system of young maize. For a better herbicidal effect, the mechanical weeding treatment is best carried out on slightly dry soil (weeds with a broken root system effectively dry out). Weeding during strong soil moisture causes secondary weed rooting. With mechanical weeding it is important to remember that the inter-rowing width should be adjusted to the wheel spacing of the tractor, as well as weeders and extirpators. The main disadvantage of the mechanical method is that it is labour-intensive and relatively low in productivity, hence it is used on a small scale.

The mechanical-chemical method consists of eliminating weeds from between the rows with mechanical tools and strip-spraying only the plant rows with herbicide. There are two options for using or combining these two methods of weed control. The first is to carry out mechanical protection for as long as possible (usually from 2 to 6 maize leaves) and, at a later stage, to carry out a chemical treatment according to the recommended agrotechnical date (e.g. 6-8 maize leaf stage). The second option is to carry out simultaneous mechanical and chemical protection. Mechanical weeding is carried out in inter-rows and herbicides are applied to the maize rows using suitable equipment that sprays the liquid in strips 15–25 cm wide. The herbicide dose should be calculated based on the actual area to be sprayed. By [illegible] presented methods meet the criteria for integrated weed management in maize to the greatest extent.

6.1.3. Chemical methods of weed infestation control

In view of the availability, cost of purchasing specialised machinery and tools, and considerable labour intensity of non-chemical methods of weed control, the use of a chemical method is also acceptable in the integrated weed management of maize. In this method, great emphasis is placed on the correct execution of the spraying procedure using approved sprayers, properly calibrated and in full working order. It is also very important to adhere to the principles of appropriate herbicide selection, recommended doses, application dates, dose reduction – through the combined use of herbicides and adjuvants as well as the rotation of herbicides belonging to different chemical groups which prevents the phenomenon of weed resistance.

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

6.2. Reduction of disease vectors

6.2.1. Most important diseases in maize cultivation

Maize plants are threatened by around 400 pathogens that are responsible for the development of a range diseases. Currently, pathogenic fungi are the most numerous, and also the most dangerous group. In recent years, increasing attention has also been paid to viruses and pathogenic bacteria that can infect maize plants, some of which can be actively transmitted by insect vectors. At this point, only certain fungal diseases are causing crop losses. Details regarding the aetiology of the pathogens responsible for specific diseases and the symptoms they cause can be found, amongst other places, in the 'Maize Protection Alert Guide' at https://www.ior.poznan.pl/plik,2811,poradnik-sygnalizatora-ochrony-kukurydzy-booklet-pdf.pdf.

Maize diseases, when conditions are favourable for their development, can lead to direct grain yield losses estimated at around 10–15 % nationally. Far more serious, however, are the indirect losses associated with a decline in the quality of the final product or raw material for further processing, including the possibility of contamination by mycotoxins whose levels in, among other things, grain and maize products are subject to rigorous controls. The current significance of maize diseases, along with the harmfulness forecast for the coming years, is shown in Table 1.

Table 1. The economic significance of selected maize disease agents

Disease (cause)	**Economic impact**	
	current	**forecast**
Bacterial leaf spot of maize (*Pantoea ananatis*)	+	+
Bacterial stalk rot of maize (*Enterobacter cloaceae* subsp. *dissolvens*)	+	+
Crazy top disease of maize (*Sclerophthora macrospora*)	+	+
Eyespot (*Kabatiela zeae*)	++	++(+)
Maize cob fusariosis (*Fusarium* spp.)	+++	+++
Maize smut (*Ustilago maydis*)	++	++(+)
Head smut of maize (*Sphacelotheca reiliana*)	+	+(+)
Maize dwarf mosaic virus and sugarcane mosaic virus (MDMV, SCMV)	+	+
Brome mosaic virus (BMV)	+	+
Common rust of maize (*Puccinia sorghi*)	++	++(+)
Wheat streak mosaic virus on maize (WSMV)	+	+
Leaf blight and vascular wilt of maize and sorghum (*Pantoea agglomerans*)	+	+
Root rot and basal stem rot (*Fusarium* spp.)	+++	+++
Seedling blight (*Fusarium* spp, *Pythium* spp.)	++	+(+)
Barley yellow dwarf virus on maize (BYDV-MAV, BYDV-PAV, CYDV-RPV)	+	+(+)
Yellow spot of maize leaves (*Helminthosporium* spp.)	+	++

+ small; ++ medium; +++ big

6.2.2. Methods for monitoring disease perpetrators in maize cultivation

In the integrated method of protection, 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 disease perpetrators. The more favourable the conditions for the development and spread of the pathogen, the greater the intensity of disease outbreaks and the associated yield losses they cause.

Currently, there is no national decision support system for protecting maize against fungal diseases, so decisions on the need for chemical treatment should be based on the grower's own observations and experience. Recording the level of severity of disease perpetrators each year is recommended, so that the risk of their appearance in the next vegetation season can be predicted in advance, especially if maize is grown in monoculture. 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. In this respect, it is important to know the history of the field, i.e. whether and what diseases and in what severity were previously observed in this area. It is important whether these were pathogens that could survive in the soil for many years.

The decision to use chemical protection against diseases should be based on one's own monitoring of the plantation's phytosanitary status and experience as commercial threat thresholds for diseases of this plant have not yet been developed. For the purpose of determining the timing of the emergence, incidence and harmfulness of maize fungal disease perpetrators, systematic observations of the crop from the time of sowing the caryopses (BBCH 00) until the harvest of the green matter or grain crop (BBCH 83-99) are essential. In the event of early spring diseases affecting germination and emergence, it may be necessary to excavate kernels in areas where emergence has not occurred, or to assess the root system of dying seedlings to determine the cause of maize dieback. For diseases occurring from the time the plants unfold the first leaves (BBCH 11), it is recommended that pathogen development is monitored at least twice a month throughout the maize vegetation season by carefully observing at least 100 randomly taken plants at four sowing sites over an area of up to 10 ha. In plantations of 10-50 ha, the number of observation points should be increased to at least 8-10, and in very large fields (over 100 ha) there should be at least 15-20 points.

In order to determine the prevalence of the majority of maize diseases, the degree of infestation of individual organs is often calculated. For the eyespot, northern maize leaf blight, and common rust of maize, a five-stage infestation scale is usually used where the first stage means an infestation of 0.1–5.0 % of the leaf blade area while the fifth stage means an infestation of more than 50 % of the leaf area. A five-stage scale is usually used for maize cob fusariosis where the first stage indicates a very small infestation (up to 2 % of kernels) and the fifth stage a very large infestation (51–100 % of caryopses infested). A 9-stage scale is usually used to assess the severity of root rot and basal stem rot with the first stage indicating no symptoms, the third stage indicating lesions on the first or second node, and the ninth stage indicating complete tissue decay.

Currently, there are no developed commercial threat thresholds for maize diseases, hence the decision to reduce them should be based on knowledge and own experience.

6.2.3. Non-chemical methods of reducing pathogens

In integrated pest management, 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 maize cultivation, the primary method of reducing the presence of pathogenic organisms is correct agrotechnology, but attention should also be paid to other non-chemical methods that reduce the risk of disease perpetrators on the site.

Cultivation method

In non-chemical methods of reducing disease perpetrators, the purchase of certified maize seed from a verified source is particularly important. Sourcing high quality, evaluated seed is important as many pathogens are transmitted on the fruit and seed coats of caryopses from where they later infect the plants.

When limiting the appearance of diseases such as maize smut, maize cob fusariosis and root rot and basal stem rot, choosing varieties less susceptible to infection is recommended for cultivation. Information on the susceptibility of hybrids to selected diseases can be found, among others, in the Variety Description Lists issued by Research Centre for Cultivar Testing. It is important that the varieties sown are adapted in terms of earliness to the local soil and climatic conditions. Under IP, seed produced by self-reproducing generation F_2 and above must not be sown.

Agronomic method

In non-chemical methods of reducing the abundance and harmfulness of disease perpetrators, an important emphasis is put on selection of the optimum growing site to ensure that the plants develop properly. Sowing maize on soils that are too weak, in shady, waterlogged areas, periodically flooded by rainwater, or located on too high a hill (risk of soil erosion) should be avoided.

Many disease perpetrators overwinter in the soil and in maize crop residues, and in the case of some pathogens, their endospore stages remain viable for up to several years so using crop rotation is very important. For the reduction of diseases caused by *Fusarium* fungi, a model crop rotation is available proving that in order to mitigate the risk of excessive multiplication and accumulation of these fungi, potato, then triticale and then lupin should be grown after maize.

The degree of threat from many disease perpetrators can be influenced by some agrotechnical treatments. Optimal fertilisation, particularly with nitrogen, is one of them. The use of nitrogen in excessively high doses contributes to an increase in the infestation of plants by maize smut and diseases caused by *Fusarium* fungi genus. In the case of some diseases, early sowing is advisable, but in soil that is sufficiently warmed up so that the plants are more advanced in their development at the time of infection.

Weed control is also important as some weed species can be overwintering or pre-development sites for certain pathogens, an example being common yellow woodsorrel (*Oxalis stricta*), an intermediate host for common rust of maize.

In smaller maize plantations, direct control of some diseases can be carried out by cutting and destroying infested plants away from the plantation. This procedure can be carried out in the case of maize tassel rot, as well as maize smut and head smut of maize.

In order to reduce quantitative and qualitative crop losses, the crop should be harvested in a timely manner. When an increase in the number of plants infected by fusarium diseases is discovered, consideration should be given to harvesting and re-drying the grain sooner rather than risking severe plant infestation by this group of pathogens which can contaminate the crop with mycotoxins.

Immediately after harvesting the crop, whether silage or grain, a crop residue chopper should be applied to the stubble to mechanically destroy some of the spores and, in addition, by cutting straw into chaff, accelerate decay. In addition, it is necessary to plough before winter to cover the overwintering stages of the pathogens with a layer of soil, making it more difficult for them to infect new maize plants in spring.

A list of the most important non-chemical methods of reducing the abundance and harmfulness of disease perpetrators is presented in Table 2.

Table 2. Non-chemical control of maize disease perpetrators

Disease	Non-chemical methods
Bacterial diseases	
Bacterial leaf spot of maize	crop rotation, spatial isolation (e.g. from previous year's post-cropped fields, waterlogged sites), purchase of 'certified' seed, early sowing, sustainable fertilisation, weed and pest control, thorough shredding of crop residues, winter ploughing.
Bacterial stalk rot of maize	
Leaf blight and vascular wilt of maize and sorghum	
Fungal diseases	
Crazy top disease of maize	crop rotation, spatial isolation (among others, from the previous year's post-cropped fields, perennial grasses, waterlogged and periodically flooded sites), purchase of 'certified' seed, early sowing, sustainable fertilisation, control of monocotyledonous weeds, cutting and removing of infested plants, shredding of crop residues, winter ploughing.
Eyespot	crop rotation, purchase of 'certified' seed, early sowing, sustainable fertilisation, weed and pest control, shredding of crop residues, winter ploughing.
Maize cob fusariosis	crop rotation, spatial isolation (e.g. from the previous year's post-cropping fields), purchase of 'certified' seed, selection of tolerant varieties (to maize cob fusariosis and stem fusariosis), early sowing, sustainable fertilisation (especially with nitrogen), weed and pest control, timely crop harvesting, shredding of crop residues, winter ploughing.
Root rot and basal stem rot	
Seedling blight	
Maize smut	crop rotation, spatial isolation (e.g. from the previous year's maizefields), purchase of 'certified' seed, selection of tolerant varieties (to maize smut), early sowing, sustainable fertilisation (especially with nitrogen), weed and pest control, removal of infested plants, shredding of crop residues, winter ploughing.
Head smut of maize	
Common rust of maize	crop rotation, spatial isolation (among others, from the previous year's post-cropped fields, common yellow woodsorrel), purchase of 'certified' seed, early sowing, sustainable fertilisation, weed and pest control, shredding of crop residues, winter ploughing.
Northern maize leaf blight	crop rotation, spatial isolation (e.g. from the previous year's post-cropped fields), purchase of 'certified' seed, early sowing, sustainable fertilisation, weed and pest control, shredding of crop residues, winter ploughing.
viral diseases	
Maize mosaic	avoiding waterlogged and periodically flooded sites, using crop rotation, using spatial isolation from the previous year's maize fields, sowing

Wheat streak mosaic virus on maize	'certified' seed, early sowing, sustainable fertilisation, weed and pest control, not using a stagnant tank water for maize irrigation, thorough shredding and deep ploughing of crop residues.
Barley yellow dwarf virus on maize	

6.2.4. Chemical methods of disease vectors control

Plant protection products should be used in accordance with the current list of plant protection products recommended for maize in integrated production (IP) based on the monitoring of disease vectors. 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 on the Online Pest Signalling Platform at: https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.

6.3. Reduction of losses caused by pests

6.3.1. Main pests in maize cultivation

Maize plants are threatened by around 100 species of herbivores, some of which are typical pests. Among these, the representatives of the insect class (Insecta) dominate. Their number is steadily increasing as new species appear from time to time, e.g.: knot grass moth, reed dagger, cotton bollworm, red spider mite, the crescent as well as those that have existed for many years but have so far been described under a general family name, e.g. thrips whose full species composition has been recently recognised. Pests are often characterised by localised emergence and high damage, but some species are common organisms. Details on morphology, biology and damage caused by pests can be found, amongst other sources, in the 'Maize Protection Monitor's Guide' at https://www.ior.poznan.pl/plik,2811,poradnik-sygnalizatora-ochrony-kukurydzy-booklet-pdf.pdf.

As a result of the most important species, average silage yield losses nationally are estimated at around 10 %, while grain maize production is estimated at 15–20 %. At the same time, the consequence of the occurrence of pests is the poor quality of the grain yield and green matter intended for silage, including the possibility of its contamination with mycotoxins.

The current importance of maize pests, along with a forecast of their damage for the coming years, is presented in Table 3.

Table 3. Economic importance of selected maize herbivores with a forecast of their damage

Pests	Economic impact	
	current	forecast
Elm sack gall aphid (*Tetraunera ulmi*)	+	+
Red sword-grass moth (*Xylena vetusta*)	+	+
Silver Y (*Plusia gamma*)	+	+
Wireworms (Elateridae)	+(+)	++
Rodents (Rodentia)	+	+(+)

Bishop’s Mitre (*Aelia acuminata*)	+	+
Leafhoppers (Bibionidae)	+	+
Maize ground beetle (*Zabrus tenebrioides*)	+	+
Aphids (Aphididae)	++	++(+)
Leaf miners (Agromyzidae)	+	+
European maize borer (*Ostrinia nubilalis*)	++(+)	+++
Crescent (*Helotropha leucostigma*)	+	+
Great green bush-cricket (*Tettigonia virdissima*)	+	+
Flea beetles (Halticinae)	+	+
Grubs (Melolonthinae)	+	+(+)
Owlet moths (Hadeninae)	+	++
Frit fly (*Oscinella frit*)	++	++(+)
Grass fly (*Elachiptera cornuta*)	+	+
Sloe bug (*Dolycoris* baccarum)	+	+
Red spider mites (*Tetranychus urticae*)	+	++
Birds (Aves)	+	+
Cutworms (Agrotinae)	+	++
Cereal leaf beetles (Oulema spp.)	+	+(+)
Colorado maize rootworm (*Diabrotica virgifera virgifera*)	+(+)	++(+)
Leafhopper (*Macrosteles laevis*)	+	+(+)
Maize leafhopper (*Zyginidia scutellaris*)	+	+
Cotton bollworm (*Helicoverpa armigera*)	+	+(+)
Turnip maggot (*Delia platura*)	+	+(+)
Snails and slugs (Gastropoda)	+	+(+)
Jarr worm (*Gryllotalpa gryllotalpa*)	+	+
Four-spotted sap beetle (*Glischrochilus quadrisignatus*)	+(+)	+(+)
Thrips (Thripidae)	++	++(+)
Knot grass moth (*Acronicta rumicis*)	+	+
Myriapods (Myriapoda)	+	+
Reed dagger (*Simyra albovenosa*)	+	+
Dock bug (*Coreus marginatus*)	+	+
Bishop bug (*Lygus rugulipennis*)	+	+(+)
Vapourer moth (*Orgyia antiqua*)	+	+
Tortrix moths (Tortricidae)	+	+(+)
Game (Mammalia)	++	++
Tortoise bug (*Eurygaster maura*)	+	+

+ small; ++ medium; +++ big

6.3.2. Methods of monitoring pests in maize cultivation

In integrated pest management, it is extremely important to monitor for the emergence of pest species (including their individual stages) to determine the need for and timing of control. The results of the observations should be recorded to document the validity of the subsequent use of chemical plant protection. Observing maize plants for the presence of pests is key to detecting the threat and responding appropriately. Monitoring should cover the period from the time the field is selected for sowing (soil analyses for pests) until the end of the growing season, including during storage of the crop (storage pests).

Monitoring for the occurrence and abundance of pest species should be carried out at least once a week and, in the case of economically very important species, sometimes 2-3 times a week, during the period of occurrence of the pest stage or the stage immediately preceding it. Table 4 presents the most important methods enabling determination of the abundance and harmfulness of selected pests.

Table 4. Observation methods to determine the timing for control of selected maize pests

Pest	Date of analysis	Method of observation
Wireworms	before sowing (BBCH 00)	Sieve the soil from pits measuring 25 x 25 and 30 cm deep. For 1 ha of maize cultivation, at least 32 soil excavations must be carried out at equal distances. With each subsequent hectare, the number of pits should be increased by 2. Determine the number of wireworms.
	From sowing to full grain maturity (BBCH 00–89)	Place pheromone traps with a pheromone dispenser designed to catch a specific species of spring beetle, on the balk around the maize plantation. Place at least 2 traps at a distance of no less than 30 metres apart in an area of 1 ha. Count trapped beetles at least once a week. The trap enables determination of the level of click beetle abundance in a given area.
Bibionidae (march flies)	before sowing (BBCH 00)	Sieve the soil from pits measuring 25 x 25 and 10 cm deep. For 1 ha of maize cultivation, at least 32 soil excavations must be carried out at equal distances. With each subsequent hectare, the number of pits should be increased by 2. Determine the number of bibionidae.
Aphids	from the 1 leaf stage to the end of the maize growing season (BBCH 11–97)	The average number of aphids per plant in a 1 ha plantation is determined by estimating the number of all live individuals once a week on 10 randomly selected plants diagonally across the field. Increase the number of plants analysed by at least 2 for each additional hectare. Discovering an average of 300 aphids per plant indicates the need for a chemical treatment. To detect aphid infestation, yellow sticky boards can be used in the crop at a frequency of 1-2 pcs. per 1 hectare.
European maize borer	from autumn to spring (after harvest)	take at least 100 maize stalks with overwintering European maize borer caterpillars from crop residues and place them in an entomological isolator kept in the field. From spring onwards, the emergence of the butterflies from their chrysalises is tracked, looking for the peak in the number of butterflies. Once a large number of butterflies are discovered, observations should be transferred to the maize

		field.
	Stage of inflorescence (BBCH 51–59)	monitoring plantations for the presence of moths should be carried out from mid-June. Place pheromone traps in the area of sowing and check at least 1–2 times a week. For pheromone traps, use 1 trap per hectare on plantations up to 10 ha, and 0.5 traps per hectare on larger plantations.
	Stage of inflorescence (BBCH 51–59)	conduct observations for the presence of egg deposits by inspecting at least 50 consecutive plants per row in 4 diagonal locations in the plantation (200 plants in total) twice a week from mid-June onwards. Discovery of the first deposits is a signal to apply the biopreparation immediately. The presence of large numbers of eggs indicates the need for a chemical control treatment within 4-10 days. A good solution is to mark the analysed plants containing the pest eggs and observe their development each time.
	Dough stage of kernels (BBCH 85)	in order to calculate the percentage of plants damaged by caterpillars, a minimum of 100 consecutive plants per row should be inspected on a 1 ha area at 4 points diagonally across the plantation, and the number of plants with feeding symptoms of the pest should be noted. The number of plants to be analysed should be increased by 100 for each additional hectare.
Grubs	before sowing (BBCH 00)	Sieve the soil from pits measuring 25 x 25 and 30 cm deep. For 1 ha of maize cultivation, at least 32 soil excavations must be carried out at equal distances. With each subsequent hectare, the number of pits should be increased by 2. Determine the number of grubs.
Owlet moths	from milk to full grain maturity of caryopses (BBCH 73–85)	within an area of 1 ha, inspect 50 consecutive plants and cobs at 4 plantation sites diagonally across the field (200 plants in total) for caterpillars. The number of plants to be analysed should be increased by 50 for each additional hectare.
Frit fly	stage of 1-3 leaves (BBCH 11–13)	inspections for the presence of eggs is carried out by collecting 5 plants in 10 places at a plantation diagonally (50 plants in total). Analysis should be carried out twice a week. If 5 or more eggs are found on 10 plants, a plant protection treatment is justified. Monitor fly infestation using yellow, white or purple vessels filled with water and detergent set up in the marginal strip at a frequency of 1-2 per hectare. The use of yellow sticky boards at a frequency of 1-2 per 1 ha has a similar effect.
	Stage of 8-9 leaves (BBCH 18–19)	in order to calculate the percentage of damaged plants, a minimum of 50 consecutive plants per row in four parts of the plantation (200 plants in total) should be inspected over an area of 1 ha. Increase the number of plants by 10 for each additional hectare.
Cutworms	before sowing (BBCH 00)	Sieve the soil from pits measuring 100 x 100 and 30 cm deep. Carry out at least two soil excavations per hectare of maize cultivation. With each hectare, the number of open pits should be increased by 2 with dimensions of 25 x 25 cm and a depth of 30 cm. Determine the number of cutworms.
	From 3–9 leaves to	place pheromone traps in the marginal strips of the sown

	waxy kernel maturity (BBCH 13–85)	field to monitor the butterfly infestation of individual cutworm species. On plantations of up to 10 ha, use 1 unit per hectare, and on larger plantations, 0.5 units per hectare, and check them at least once a week. A significant increase in butterfly numbers indicates the risk of caterpillar occurrence.
	From 3–9 leaves to the 2–3 nodes (BBCH 13-19 to 32-33)	within an area of 1 ha, inspect 50 consecutive plants at 4 plantation sites diagonally across the field (200 plants in total) for caterpillars. The number of plants to be analysed should be increased by 50 for each additional hectare. Detection of 1-2 caterpillars per 1 m^2 of field justifies chemical treatment.
	From early milky to dough (BBCH 73–85)	within an area of 1 ha, inspect 50 consecutive plants and cobs at 4 plantation sites diagonally across the field (200 plants in total) for caterpillars. The number of plants to be analysed should be increased by 50 for each additional hectare.
Colorado maize rootworm	from 9 leaves to tassel (BBCH 19–59)	in monoculture plantations, to determine larvae abundance, every week take a minimum of 10 roots with surrounding soil at five points diagonally across the plantation (50 plants in total). It will be helpful to submerge the roots along with the soil in water with added table salt to cause the larvae to swim towards the surface of water.
	3 nodes to tassel (BBCH 33–51)	in order to calculate the percentage of plants damaged by larvae on an area of 1 ha of maize grown in monoculture, take 10 roots at random at 10 sowing locations on a diagonal (100 plants in total), looking for signs of feeding by the pest. Assess the damage to the root system using the IOWA 6-point scale, where step 1 means no damage and step 6 means complete root destruction. The analysis is recommended to be carried out twice in the following 2 weeks due to the possible rapid production of secondary roots by the plants.
	From 4 nodes till the end of vegetation (BBCH 34–97)	To determine the beetle population on plantations of up to 10 ha, one trap per hectare should be used; on larger plantations, 0.5 traps per hectare. Check traps twice a week from July to October. A significant increase in the number of beetles caught is a signal to carry out a chemical control treatment. From August onwards, it is additionally recommended to use food traps to attract insects of both sexes. The presence of beetles can also be detected by using bright green sticky boards mounted on plants at a frequency of 1–2 per hectare.
Other species	from sowing to harvest (BBCH 00–99)	in order to detect the abundance and harmfulness of aboveground pest species in an area of 1 ha, 100 consecutive plants per row should be inspected at least once a week at four points in the plantation (diagonally). Increase the number of plants by 50 for each additional hectare. Non-selective yellow sticky boards will also be helpful as well as blue ones for thrips detection for monitoring. 1-2 pcs. should be used per 1 hectare.

As soon as economically important pests are detected, the decision to carry out a chemical treatment should be made on the basis of commercial threat thresholds. The commercial harmfulness threshold is the severity of the pest at which the value of the expected loss in the yield is higher than the total costs of treatment. The commercial harmfulness thresholds relating to pests are one of the most important and, at the same time, most difficult to determine aspects of chemical plant protection. The commercial harmfulness threshold values may not be treated unambiguously. Depending on the stage of plant development, climatic conditions or the occurrence of natural enemies, the value of the threshold may change. The commercial threat thresholds only serve as an aid in decision making, but cannot be the only criterion to be taken into account as the maize grower's years of experience and practical knowledge are equally important. The current commercial threat thresholds apply to six pests appearing in maize crops and are presented in Table 5.

Table 5. Commercial threat threshold of maize pests

Pest	Observation date	Economic damage threshold
Wireworms	before sowing (BBCH 00)	2–8 larvae per 1 m^2 of the field
Bibionidae (march flies)	after emergence (from BBCH 10 onwards)	10 larvae per 1 m^2
Aphids	from tassel (BBCH 51)	300 aphids on 1 plant
European maize borer	tassel stage (BBCH 51-59)	6–8 egg deposits per 100 plants or when 15 % of grain maize plants or 30–40 % of silage and CCM plants were damaged in the previous year
Frit fly	from emergence to 4 leaves (BBCH 10–14)	damage to 15% of plants in the previous year
Cutworms	emergence (BBCH 10-14)	1 caterpillar per 2 m^2 of the field
	5-6 leaves (BBCH 15-16)	1-2 caterpillars after the 3rd exuviae per 1 m^2 of crop

6.3.3. Non-chemical methods of reducing the abundance of maize pests

Cultivation method

When reducing the occurrence of the European maize borer, it is advisable to select varieties that are less susceptible to damage. Information on the susceptibility of hybrids to selected pests can be found in the Variety Description Lists issued by Research Centre for Cultivar Testing, among others. It is important that the varieties sown are adapted in terms of earliness to the local soil and climatic conditions. Seed produced by self-reproducing generation F_2 and above must not be sown.

Agronomic method

In non-chemical methods of reducing the abundance and harmfulness of disease perpetrators, an emphasis is placed on selection of the optimal growing site to ensure that the plants develop properly.

Many pests overwinter in the soil and in maize residues, so it is very important to use crop rotation as well as to shred crop residues very thoroughly after harvesting and mix them into the soil so that they decay more quickly.

The degree of threat from many pests can be influenced by certain agrotechnical treatments. Optimal fertilisation, particularly with nitrogen, is one of them. The use of nitrogen in excessively high doses contributes to an increase in the damage of plants by the European maize borer. Early sowing is recommended, but soil must be sufficiently warmed so that the plants are more advanced in their development when the spring species emerge.

Weed infestation control is also important as some weed species can provide overwintering or pre-development sites for certain pests, e.g. the European maize borer, aphids and thrips.

In order to reduce quantitative and qualitative crop losses, the crop should be harvested in a timely manner. A list of the most important non-chemical methods of reducing herbivore abundance and damage is presented in Table 6.

Table 6. Non-chemical methods of protecting maize against pests

Pests	Ways of reducing harmfulness
Red sword-grass moth	correct agrotechnology, weed control, spatial isolation (from wetlands and main host plants, e.g. great water dock, maizeflower, true sedges, irises, knotweeds),
Silver Y	correct agrotechnology, control of Amaranthaceae weeds, spatial isolation (from other host plants such as brassicas, oilseed rape, beet, potato), shredding of crop residues, early and deep autumn ploughing,
Helotropha leucostigma	correct agrotechnology, weed control, spatial isolation (from wetlands and main host plants, e.g. sweet flag, true sedges, bur-reed, irises),
Wireworms and grubs	correct agrotechnology, crop rotation, shallow tillage, disc harrowing, harrowing, selection of varieties with extensive root systems and fast initial growth, early sowing, increased sowing standard, soil loosening, weed control, spatial isolation (from uncultivated land, meadows, pastures and forests), shredding of crop residues, autumn ploughing,
Rodents	correct agrotechnology, crop rotation, shallow tillage, disc harrowing, harrowing, soil loosening, weed control, mowing grass around the plantation, spatial isolation (from uncultivated land, meadows, pastures and cereal crops), autumn ploughing,
Bibionidae (march flies)	correct agrotechnology, crop rotation, ploughing, spatial isolation (from wetlands and cereal crops), early sowing, increased sowing standard,
Leaf miners	correct agrotechnology, sustainable fertilisation (from cereal crops, permanently uncultivated green land), weed control,
Aphids	correct agrotechnology, sustainable fertilisation (mainly with nitrogen), spatial isolation (from host plants such as maize, cereals, bird cherry, wild and garden roses, elm, meadows, pastures, waste land), early sowing, weed control, protection of beneficial insects,
European maize borer	correct agrotechnology, crop rotation, selection of varieties less susceptible to the pest, shallow tillage, disc harrowing, sustainable fertilisation (especially with nitrogen), spatial isolation (from other maize fields, maize residues and other host plants, e.g. hops, millet), use of biopreparations, early harvesting, shredding and deep ploughing of crop residues immediately after harvesting, collection of crop residues directly after harvesting, removing of crop residues from the field and their processing into briquettes, deep autumn ploughing,
Great green bush-cricket	spatial isolation (from meadows, pastures, waste land), weed control,

Flea beetles	correct agrotechnology, sustainable fertilisation, early sowing, spatial isolation (from brassica vegetables, oilseed rape, beet, cereals), weed control,
Meadow froghopper	spatial isolation (from wetlands, meadows, pastures, waste land), sustainable fertilisation, weed control,
Hadeninae and cutworms	correct agrotechnology, crop rotation, shallow tillage, disc harrowing, spatial isolation (from brassicas, rape, waste land, cereals, wetlands), sustainable fertilisation, selection of varieties with a developed root system, early sowing, increased sowing standard, weed control, shredding of crop residues, autumn ploughing,
Grass fly	correct agrotechnology, sustainable fertilisation, early sowing, weed control, spatial isolation (from winter cereals, meadows, pastures),
Frit fly	correct agrotechnology, shallow tillage, early sowing, weed control, cultivation of less susceptible varieties, in high-risk areas – cultivation of varieties with fast initial growth, spatial isolation (from winter cereals, meadows, pastures),
Red spider mites	correct agrotechnology, crop rotation, weed control,
Birds	early sowing, increased sowing standard, spatial isolation (from larger forest stands), use of acoustic and light deterrents,
Cereal leaf beetle	correct agrotechnology, early sowing, spatial isolation (from cereal crops), sustainable fertilisation,
Leafhopper Maize leafhopper	correct agrotechnology, early sowing, spatial isolation (from cereal crops), sustainable fertilisation,
Cotton bollworm	correct agrotechnology, crop rotation, weed control, shredding of crop residues, deep autumn ploughing,
Colorado maize rootworm	correct agrotechnology, crop rotation, selection of varieties with extensive root systems, spatial isolation (from monoculture maize fields), early sowing, weed control, shredding of crop residues, deep autumn ploughing,
Snails	correct agrotechnology, crop rotation, shallow tillage, disc harrowing, careful tillage, soil liming, spatial isolation (from cereals, oilseed rape and brassicas), early deeper sowing, increased sowing standard, weed control, mowing of grass around the plantation, shredding of crop residues, autumn ploughing,
Turnip maggot	correct agrotechnology, crop rotation, selection of varieties with fast initial growth, early sowing, increasing the seed sowing rate, weed control, accurate manure stubble ploughing, shredding of crop residues and their stubble ploughing,
Jarr worm	correct agrotechnology, crop rotation, weed control, mowing of grass around the plantation, spatial isolation (from wetlands, orchards, forests and vegetable crops), shredding of crop residues, autumn ploughing,
Four-spotted sap beetle	correct agrotechnology, crop rotation, spatial isolation (from orchards and vegetable crops), timely crop harvesting, shredding of crop residues, autumn ploughing,
Thrips	correct agrotechnology, early sowing, spatial isolation (from cereals, waste land and grassland), sustainable fertilisation, weed control, autumn ploughing,
Knot grass moth	correct agrotechnology, crop rotation, spatial isolation (from meadows, forests, mid-field woodlands and wetlands), weed control,
Reed dagger	correct agrotechnology, crop rotation, spatial isolation (from meadows, forests, mid-field woodlands and wetlands), weed control,
Lygus bugs	correct agrotechnology, crop rotation, sustainable fertilisation, spatial isolation (from meadows, pastures and waste land), cultivation of varieties with compact cob cover leaves, weed control, early crop harvesting,
Vapourer moth	spatial isolation (from larger deciduous and coniferous forest stands),
Game	early sowing, increasing sowing standards, spatial isolation (from larger forest stands), use of acoustic, light, chemical repellents, construction of permanent

	fencing,
Leafroller moths	correct agrotechnology, spatial isolation (from cereal crops), sustainable fertilisation (especially with nitrogen), weed control,
Other species	correct agrotechnology, crop rotation, plant care treatments.

6.3.4. Chemical methods of pest control

Plant protection products should be used in accordance with the current list of plant protection products recommended for maize in integrated production (IP) based on the monitoring of pests. The messages provided in the Online Pest Warning System (www.agrofagi.com.pl) may be helpful. Before use, please read the label on the plant protection product.

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

7. BIOLOGICAL METHODS IN INTEGRATED MAIZE PROTECTION

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 conditions and covered ground. Biological methods, in most cases, are slower in terms of speed of action than classical chemical protection. This is influenced by a number of factors, such as environmental conditions, but also biology itself and the mechanism of influence of the biological agent on the restricted pest species. Biological methods may be interventional, but in most cases they work preventively, reducing the abundant development of the harmful species. Sometimes they require multiple applications of a biological agent in order to maintain effectiveness at a satisfactory level.

In biological pest control, three main methods exist:

- **the classical method** involving the introduction, i.e. permanent settlement in new areas of natural enemies, imported from other regions or continents;
- **the conservation method** that consists of the protection of beneficial organisms by making positive changes in the environment and the use of selective plant protection products;
- **the augmentative method** that involves temporary colonisation, i.e. a periodic introduction of natural pest enemies in a crop where they do not occur at all or occur in small numbers.

Naturally occurring micro- and macroorganisms can occur in maize crops. 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 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 maize cultivation, spider mites which are infested 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, among others, *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, which can be found in the soil environment under natural conditions and are important in reducing disease pathogens.

A biopreparation containing the fungus *Trichoderma asperellum* may be used during the sowing of maize. The formulation is designed to reduce development of root rot and stem base rot as well as maize cob fusariosis. The *Trichoderma* fungus is designed to compete with pathogenic fungi, hence it is used preventively, while at the same time it can parasitise pathogenic fungi itself, hence it has an intervention effect. This fungus develops at temperatures of 10-25 ^{o}C and is favoured by a soil pH of 5.0-9.0.

In integrated production, biological products containing microorganisms that have been authorised for marketing may be used.

It should be remembered that biopreparations based on macroorganisms (nematodes, hymenoptera, flies, beetles, among others) are not subject to registration in Poland, hence they can be used in maize crops if the manufacturer indicates their use. An example is the Hymenoptera of the Trichogramma genus (*Trichogramma* spp.), which is a natural enemy of the European maize borer. It is an oophage, a species parasitising the eggs of this species. Trichogramma is commonly used in maize crops. In Poland, biopreparations are available on the market that contain mainly one species of trichogramma – *T. brassicae*.

In monoculture crops, where the presence and harmfulness of root-damaging Colorado maize rootworm larvae is a problem, biopreparations containing the *Heterorhabditis bacteriophora* insecticidal nematode can be used by application at the time of sowing maize.

The biological method of control for naked snails using a biopreparation containing infective forms of the *Phasmarhabditis hermaphrodita* nematode species is also applicable in integrated production. The formulation is applied as a spray on plants and soil.

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

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

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 10 ha).

8. PROTECTION OF USEFUL ENTOMOFAUNA FOUND IN MAIZE PLANTATIONS

Protection of bees and other pollinators

As a monoecious and wind-pollinated crop, maize is not directly dependent on pollinating insects. However, its crops may have pollinators, including the European honey bee. During the flowering period of maize, pollen-collecting workers may appear. This usually occurs when the bees, while flying to a better feeding location, encounter maize plantations. In addition, the European honey bee and other beneficial insects can be found on maize leaves covered with aphid honeydew. It is also important to remember that mass flowering weeds in but also near the crop attract significant numbers of pollinators. Therefore, while caring for the agricultural environment as a whole and its biodiversity, this should also be taken into account when applying chemical protection to plants that are not pollinated by insects.

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 harmful organisms.

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 maize 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 the edges or patches should be considered if the pest does not occur on the whole plantation. The use of tested mixtures of plant protection products and liquid fertilisers should be recommended as it reduces the number of entries into the field and mechanical damage to plants;
- 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 maize 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.

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 plant production whose basic element is integrated pest management requires producers to provide reasonable protection based on the greatest possible use of useful activity of parasites and predators.

Very efficient pollinators are insects that live in the wild in agrocenoses. 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

In arable crops, including maize, the main method of conservation is beneficial use, i.e. the use of landscape elements in agricultural and forest areas that enable and promote the development of the population of naturally occurring beneficial organisms. The main aim of the measures taken is to improve habitat quality for these organisms by diversifying the landscape, creating hiding places and suitable overwintering sites, and securing a feeding base for naturally occurring enemies of agrophages. The rational use of selective chemicals to reduce their negative impact on beneficial organisms is also a very important part of this strategy.

Maize fields provide good habitats and growth conditions for many insect species. Many species of parasitic and predatory insects live in the crops as well as on the balks which assist farmers in reducing herbivore abundance. High plant species diversity in agroecosystems is important. In addition, the creation of vast fields and the removal of agriculturally unproductive thickets and mid-field shrubs is reducing the natural plant communities that provide habitats for beneficial insects. They are an important part of the natural resistance of the environment to pest gradation. Therefore, it is important to observe not only pests in cultivated fields, but also their natural enemies, whose role is very often underestimated. Hence, these allies are worth getting to know well in order to prevent their careless destruction. Within the relationships occurring between a pest and its natural enemy, predation – where a predator is an organism that kills and eats individuals of another species (predator-prey system) – is one important factor. The second form of coexistence between two organisms is parasitism, where one benefits from the coexistence and the other suffers harm from it.

One of the most important groups of predators found in the agroecosystem are ground beetles because, being non-specialised predators, they fulfil an important role as natural enemies of plant pests. The predatory insects of the ground beetle (Carabidae) family are of great importance. The Carabidae family is one of the more numerous groups of insects. It includes more than 500 beetle species. Most of them lead a ground-based life – on the surface and in the top layers of organic soil where they feed, reproduce, and overwinter. A distinction is made between epigeal, litter-soil, and soil Carabus beetles. Most adult insects, as well as larvae, feed at night. Their prey can include insect larvae and adults, annelids, snails and other small organisms, including predatory organisms. Carabidae prey also includes aphids, ants, butterfly caterpillars, among others, of cutworms, or larvae, immobile insect pupae, and earthworms. A factor influencing the diversity and size of Carabidae groupings is mineral and organic fertilisation. Carabidae can be an indicator of biodiversity in temperate climate phytocoenoses because of their well-studied systematics and the ease of obtaining material. In the Wielkopolska region, *Harpalus rufipes* accounted for about 50% of the groupings surveyed in fields where integrated production is applied. Other species found in the fields were: *Calathus ambiguus*, *Bembidion quadrimaculatum* and *Poecilus cupreus*, and *Pterostichus melanarius.*

Rove beetles (Staphylinidae) are also pest-reducing insects. This is the most numerous family of insects, represented by more than 1,400 species. They hunt both larval and adult forms for various small organisms. The most common species among *Staphylinidae* include: rove beetle (*Aleochora bilineata*), *Tachyporus hypnorum* and *Philonthus fuscipes*. They occur in a variety of environments. Species diversity of Staphylinus is much higher at the edges of forests and woodlands than in the central part. Rove beetles are thought to be poorly specialised predators, predominantly hunting incidentally, destroying eggs of insects such as the European maize borer, larvae and pupae of cereal leaf beetle, larvae of bishop bugs, and small arthropod species unprotected by a thick chitin carapace. The more numerous they are in the soil, the less chance of mass reproduction for many herbivore species. This is mainly the case for herbivores which reside in the soil in their diapausing stages, providing a good food base for carabidae and rove beetles.

Ladybirds (Coccinellidae) are very important in maize cultivation. There are 3,500 species of ladybird described worldwide. Ladybirds are natural enemies of scale insects, whiteflies and mites. These insects are important regulators of aphid abundance in agrocenoses. A number of factors can influence the dynamics of ladybird abundance, one of the most important being the synchronisation of the predator-prey system. The most common ladybirds include: multicoloured Asian ladybird (*Harmonia axyridis*), seven-spot ladybird (*Coccinella septempunctata*), two-spot ladybird (*Adalia bipunctata*), 14-spotted ladybird beetle (*Propylea quatuordecimpunctata*) and lesser mite destroyer (*Stethorus punctillum*). Despite the fact that the Asian ladybug is an invasive species, as an efficient predator it effectively limits colonies harmful to insect plants. Ladybird larvae of different species are capable of destroying up to 2 000 aphids during their development. Adult insects eat between 30 and even 250 of these pests per day. The larvae and adults of the spider mite (*Stethorus pusillus*) can also be found on maize leaves infested with spider mites.

Certain flies (Diptera) are important predatory insects, mainly those belonging to the flower flies (Syrphidae) and tachinid flies (Tachinidae) families. Flower fly larvae are among the most important natural enemies of aphids. The most effective action of their larvae takes place during the mass emergence of aphids. During larval development, one individual destroys between 200 and 1 000 aphids.

A huge role in natural conditions in limiting populations of many harmful insects is played by flies of the tachinid family (Tachinidae). 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 attract them close to agricultural land and orchards is of great practical importance for the protection of the maize and provides a food base for this parasitoid.

Among the parasites that naturally limit the populations of aphids in maize 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 maize 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.

Representatives of net-winged insects (Neuroptera), whose larvae have sickle-shaped chews adapted to hollow out other insects, lead a predatory lifestyle. The dominant species, common green lacewing (*Chrysoperla carnea*), is particularly important in reducing the number of maize pests. Apart from aphids, larvae of green lacewings also eat eggs of other harmful insects and spider mites. In addition to the common green lacewing, a brown lacewing (*Micromus angulatus*) can also be found in aphid colonies, feeding on a variety of aphid species.

Among heteropterans predatory species representing the plant bug (Miridae), minute pirate bug (Anthocoridae) and shield bug (Pentatomidae) families are of great importance.

They use their stylets like swords for killing, and then hollow out their victims. Their food includes spider mites, aphids, thrips, and butterfly eggs. 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. Species of the damsel bugs (Nabidae) family are also important.

In natural conditions, earwigs (Dermaptera) are also included among beneficial insects. They are polyphagous insects. 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.

Spiders play an underestimated role 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. 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. 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. For this reason, it is necessary to create stable places for such organisms, in which they can winter and develop.

9. PROPER SELECTION OF PLANT PROTECTION TECHNIQUES

Storage of plant protection products

Plant protection products should be stored:

a) in original packaging, sealed and clearly labelled and in a way that prevents contact with food products, beverages 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;

In accordance with the good practice principles, plant protection products should be stored in separate rooms (outside residential and livestock buildings). These rooms should be clearly labelled (e.g. sign: '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, attested to by a certificate of completion of training in the use of plant protection products or advisory on plant protection products and integrated plant production or another document attesting to their rights to carry out plant protection treatments.

The sprayer operator must be equipped with appropriate protective clothing, as prescribed by the label. 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 **Good Plant Protection Practice**.

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' (https://www.agrofagi.com.pl/553,kodeks-dobrej-praktyki-ochrony-roslin) or other subject studies in this area.

Choice of plant protection product and dosage

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

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

The dose of the plant protection product should be selected according to the 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 treatments with the use of the product during the season,**
- **the maximum dose of the plant protection product.**

Selection of spray liquid volume

In integrated cultivated plant production, the volume of spray liquid (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 (among others, sprayers with an auxiliary air stream [AAS]), the liquid dose can be 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 quantity and preparation of the spray liquid must 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 (among others, a concrete slab) in a place where it is possible to prevent the spread 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 out 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 (including 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. It is recommended that they be pre-diluted before pouring into the sprayer tank. Start with an adjuvant that improves compatibility of the components of the mixture, if used. Then plant protection products are added (in the correct order – according to the formulation) 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.

For the treatment, do not use water at low temperature (collected directly from the deep well. Very hard and contaminated water should not be used. Protective treatments may begin when the spray liquid is properly prepared.

Treatment conditions

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

Treatments with plant protection products should be carried out in light wind and rain-free weather and moderate temperature and sunshine. Spraying during 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 7 shows recommendations for optimal and limiting weather conditions during spray applications. The recommended air temperatures during treatments are conditioned by the type and mechanism of action of the plant protection product applied and such details are included in the label texts. For most preparations, optimal effectiveness is achieved at a temperature range 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 7. 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 first with the labelling of plant protection products. On many labels, distances (buffer zones) greater than those indicated above are provided from specific sites and facilities after which plant protection products should be used.

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.

Procedure for rinsing the tank and liquid system

- to rinse use the least amount of water required (2-10 % of the volume of the tank or an amount that dilutes any remaining liquid in the tank 10 times) – it is recommended to rinse the liquid system with a small portion of water 3 times,
- Turn on the pump and rinse all the elements of the liquid system used during the procedure.

- Spray the rinsings on previously sprayed surface or, if it is not possible, use the residues according to the recommendations on the management of liquid residues.
- The residual liquid drained from the sprayer must be disposed of using technical equipment that ensures biodegradation of the active substances contained in plant protection products. Until neutralisation or disposal, liquid residues may be stored in a sealed, labelled and secured container earmarked for that purpose.

External sprayer washing

After the end of the working day, 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 (inter alia, 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.

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) farmed and domestic animals have no access to the rooms, vehicles or packaging;
d) harmful organisms (agrophages 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. CROP HARVESTING

The correct harvesting period is a very important element of maize agrotechnology which determines the size and quality of the yield. It is so important that in any farming system, and especially in integrated production, it should be set with due precision.

Determining the right harvesting date for maize is difficult because, on the one hand, delay is associated with a desirable decrease in the water content of the grain, but on the other hand, weather conditions in autumn often increase losses due to the development of pests and diseases, especially those caused by *Fusarium* spp. species fungi and those of respiration of hydrated germs in moist grain.

The black spot stage is an indicator of maize plant maturity. Modern maize varieties reach the black spot stage at a moisture content of around 35%, but, depending on the variety, this value can vary from 31% (early variety) to 37% (mid-early variety). Determining this stage under field conditions is the basis for determining the correct time to harvest maize for grain. The date when threshing maturity is reached depends on the earliness of the variety and the weather.

An important indicator of the maturity of maize grain is its moisture content. The maize grain will not accumulate the maximum amount of dry matter before its moisture content falls below 35% or even 28%. The above grain moisture limits are also indicators of maize grain maturity. Technically, harvesting with a harvester can begin when the water content of the grain has dropped below 38%, but such an early harvest is not advisable due to the physiology of the plant. It is extremely important to harvest grain with the lowest possible moisture content. Delaying harvesting leads to a systematic decrease in the water content of the grain. The greatest drop in moisture occurs two weeks after the black spot stage, while delaying harvesting until early December even increases the water content of the grain.

The possibility of using maize grain for specific industrial purposes is determined by the subspecies of maize, type of grain, harvest date and drying process. The suitability of grain for industrial use is determined by the structure of the endosperm and its proper formation. In addition, the ease of separation of the germ from the rest of the kernel and the type of starch are very important.

The starch content of the grain dry matter shows great stability when the harvest is delayed. Grain destined for starch and ethanol production can be harvested without a drop in starch concentration up to 6 weeks after the black spot stage, but because of yield reductions, earlier harvesting, i.e. 2-4 weeks after the black spot stage, should be preferred.

The forage value of maize for whole-crop silage varies primarily according to the developmental stage and, to a lesser extent, agrotechnical factors. During the generative development period of 50-60 days, i.e. from the beginning of cob setting until full grain maturity, the energy value of the yield can increase by up to 76 GJ/ha. As the vegetation progresses, starting from the inflorescence emergence stage, the energy value of dry matter increases. There is an increase in soluble sugars and hemicellulose, and a decrease in protein, fibre and lignin.

Maize achieves its highest whole-plant dry matter yield relatively late, at the beginning of full grain maturity. In view of this, harvesting at late dough or even full maturity is most favourable. At this stage of maturity, maize contains 30-35% dry matter with a high proportion of cobs in the dry matter yield, reaching 50-60%. The parameters for good raw material for silage have been defined as follows: late dough to early full grain maturity, whole plant dry matter content of 30-35% and over 50% proportion of cobs in dry matter.

Determining the technical maturity of silage maize on the basis of organoleptic assessment or dry matter content of grain and cobs is not very precise. The moisture content of the stems and leaves and the proportion of cobs in the silage raw material should also be taken into account. In order to determine the optimum date for harvesting maize for silage under farm conditions, it is necessary to assess the maturity of the grain (waxy, beginning of full), the proportion of cobs in the fresh weight (over 40%) and the condition of stems and leaves (green, drying). Another indicator of the advanced maturity of maize plants is the location of the so-called milk line in the caryopses. According to this indicator, the optimum harvest date is reached by the maize plant when the milk line is half or 2/3 of the caryopsis length towards the germ.

Achieving optimum maturity for silage harvesting largely depends on the characteristics of the varieties grown. In some regions of the country, late varieties (FAO > 290) only reach silage maturity when the weather is favourable and the growing season is extended. Varieties with a shorter growing season yield more faithfully and, in cold years, their yields generally have a better forage value than those of late varieties. However, these varieties have lower production potential in terms of both dry matter yield and energy units. In the evaluation of hybrids for silage, an important indicator for assessing forage value is digestibility which also depends on the genotype.

In addition to the advancement of development and the condition of the plants destined for silage raw material, the forage value of the silage produced depends to a large extent on the height of cutting of the plants and the fineness and shredding of the grains. Adjusting the cutting height is a good way of increasing the concentration of energy in the forage at the time of harvest. Maize prepared for silage should be cut into 5-8 mm sections, making it easier to compact it in the silo. There should be 10-15% longer fragments in the chopped mass, ensuring good intestinal peristalsis.

It is of particular importance to maintain the time regime within which the raw material should be harvested and ensiled. Ideally, this process is carried out continuously and completed by sealing the silo within a maximum of 24 hours. Otherwise, the compacted silage rises and air begins to penetrate the deeper layers, leading to the growth of undesirable aerobic microorganisms.

12. MAIZE DEVELOPMENT STAGES BASED ON THE BBCH SCALE

Scales describing the development of crop plants are of use to plant producers and advisers in accurately determining the developmental stage of a plant, among others, during cultivation work and the application 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.

Maize – *Zea mays* L.

CODE	DESCRIPTION
Principal growth stage 0: Germination	
00	Dry seed (caryopsis)
01	Beginning of kernel swelling
03	End of kernels swelling
05	Radicle emerges from kernel
06	Radicle elongated, root hairs and/or side roots visible
07	Leaf shed (coleoptile) emerged from the kernel
09	Coleoptile breaks through to the soil surface (soil cracking)
Principal growth stage 1: Leaf development[1, 2]	
10	First leaf is formed from the coleoptile
11	1st leaf unfolded
12	2nd leaf unfolded
13	3rd leaf unfolded
1 .	Stages continue until…
19	9 or more leaves have unfolded
Principal growth stage 3: Stem elongation (shoot elongation)	
30	Beginning of stem elongation
31	1 nodes detectable
32	2 nodes detectable
33	3 nodes detectable
3 .	Stages continue until…
39	9 or more nodes detectable[3]
Principal growth stage 5: Inflorescence emergence, heading	
51	Beginning of tassel emergence: tassel detectable at top of stem
53	Tip of tassel visible
55	Middle of tassel emergence: middle of tassel begins to separate
59	End of tassel emergence: tassel fully emerged and separated

Principal growth stage 6: Flowering, anthesis

61 (M) Stamens in middle of tassel visible
Female: tip of ear emerging from leaf sheath

63 (M) Beginning of pollen shedding
Female: tips of stigmata visible

65 (M) Upper and lower parts of tassel in flower
Female: stigmata fully emerged

67 (M) Flowering completed
Female: stigmata and pistil collars drying (browning)

69 End of flowering: stigmata and pistil collars completely dry (dead)

Principal growth stage 7: Kernel development

71 Development of the first grains of aqueous consistency
which contain about 16 % dry matter

73 Beginning of milk stage of kernels

75 Kernels are fully mature and contain approximately 40% dry matter.

79 Nearly all kernels have reached final size

Principal growth stage 8: Ripening

83 Early dough: kernel content soft, about 45 % dry matter

85 Full waxy ripeness of kernels: kernels with typical colour contain about 55% dry matter.

87 Physiological ripeness: visible black spots at the base of the kernels contain approximately 60% dry matter.

89 Fully ripe: kernels hard and shiny, about 65% dry matter

Principal growth stage 9: Senescence

97 Plant dead and collapsing

99 Harvested product

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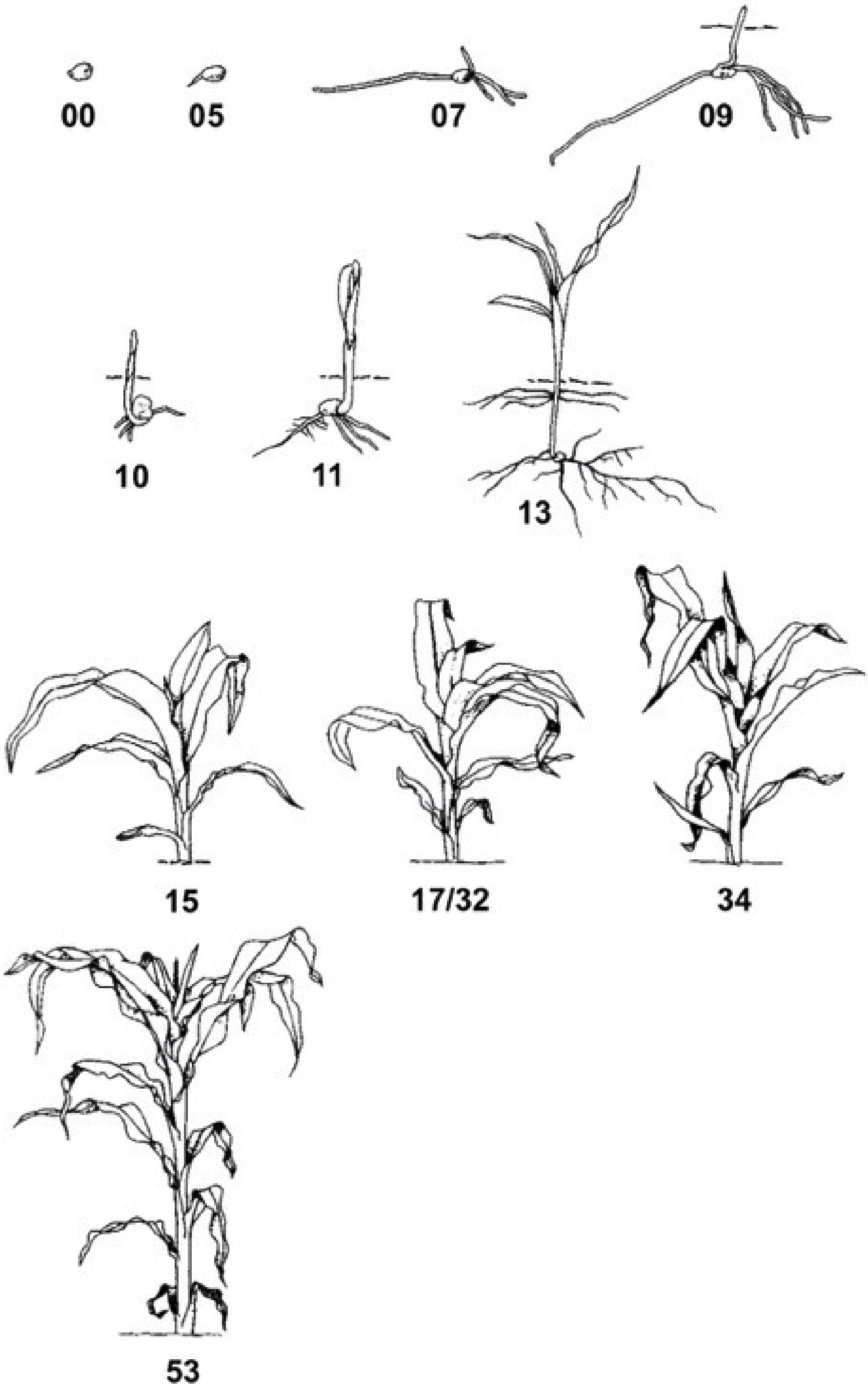
[1] A leaf is developed when its ligule or the tip of the next leaf is clearly visible

[2] Shoot elongation may take place earlier than stage 19 in which case it continues into the principal growth stage 3

[3] Tassel emergence may occur earlier, in this case continue with principal growth stage 5

Kukurydza



Kukurydza Maize

Fig. 1. Development stages of maize (*Zea mays* L.) on the BBCH scale.

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

Mandatory requirements (compatibility of 100%, i.e. 12 points)			
Item	**Control points**	**YES/NO**	**Comment**
1.	The use of an appropriate crop rotation (with very good or good preceding crops) as recommended in the methodology (**see Chapter 2.3**).	❑/❑	
2.	Selection of varieties according to the RCFCT guidelines (**see Chapter 3**)	❑/❑	
3.	The use of ‘certified’ seed category and sowing at the time appropriate for the region, with the correct standard and sowing parameters (**see Chapters 3 and 4.2**).	❑/❑	
4.	Conducting a soil test at least once every 4 years in an accredited laboratory (**see Chapter 5**)	❑/❑	
5.	Use at appropriate dates and doses of macro and micronutrient fertilisation according to soil type and pH after a nutrient balance has been carried out (**see Chapter 5**)	❑/❑	
6.	The use of mechanical methods, e.g. weeders, as a first step in weed infestation control and, in the case of chemical protection, the correct post-emergence application of herbicide in the correct dose (**see Chapter 6.1.2**)	❑/❑	
7.	Systematic monitoring from emergence to maturity, at least twice a month, of disease incidence (including seedling blight, eyespot, northern maize leaf blight, common rust of maize, maize cob fusariosis and root rot and basal stem rot) (**see Chapter 6.2.2**)	❑/❑	
8.	Systematic monitoring from emergence to the beginning of maturity, at least once a week, of pest incidence (e.g. wireworms, grubs, cutworms, aphids, European maize borer, Colorado maize rootworm) using appropriate methods (direct visual inspection of plants, pheromone traps, light traps, etc.) (**see Chapter 6.3.2**)	❑/❑	
9.	Carrying out at least one treatment with biological pesticides to control a pest (e.g. European maize borer and/or Colorado maize rootworm) or a maize disease (e.g. maize cob fusariosis) (**see Chapter 7**)	❑/❑	
10.	Creating the right conditions for the presence of birds of prey, i.e. setting up resting poles at least 1 for every 10 ha of plantation (**see Chapter 7**)	❑/❑	
11.	Setting up ‘houses’ for mason bees or bumblebee mounds, or other facilities for pollinating insects in the number of at least 1 for every 5 hectares (**see Chapter 8**)	❑/❑	
12.	Timely crop harvesting at harvest maturity of a plant (**see Chapter 11**)	❑/❑	

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)			
Item	**Control points**	**YES/NO**	**Comment**
1.	Does the producer produce and protect the crops according to detailed methodologies approved by the Main Inspector?	❑/❑	
2.	Does the manufacturer have up-to-date IP training attested by a certificate?	❑/❑	
3.	Does the producer only use plant protection products included in the list of IP approved products for the given crop?	❑/❑	
4.	Are all the documents specified in the methodology and logbook (e.g. test results, proof of purchase) present 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 application 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	❑/❑	

Basic requirements (100% compliance, i.e. 27 points)			
Item	**Control points**	**YES/NO**	**Comment**
	necessary minimum?		
13.	Does the producer have measuring devices to precisely determine the quantity of the measured plant protection product?	❑/❑	
14.	Does the producer with the instructions on the label regarding the preparation of the working solution, the disposal of any remaining solution and the cleaning of the equipment?	❑/❑	
15.	Does the producer comply with the label's instructions regarding 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, not being exceeded (if the IP methodology imposes stricter requirements than the label, the provisions of the IP methodology are to be followed)?	❑/❑	
19.	Were the sprayers listed in the IP notebook in good working order and did they have valid technical inspection certificates 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 space 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 access of third persons?	❑/❑	
23.	Are all plant protection products stored exclusively in their original packaging and in such a way as to prevent them from coming into contact with food,	❑/❑	

Basic requirements (100% compliance, i.e. 27 points)			
Item	**Control points**	**YES/NO**	**Comment**
	drink or animal 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?	❑/❑	
25.	Is each fertilisation applied recorded in the IP notebook including the type of fertiliser, date of application, dose, location and surface?	❑/❑	
26.	Did the producer perform all the necessary agrotechnical procedures in accordance with IP methodologies?	❑/❑	
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)			
Item	**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 PPP packaging against unauthorised access?	❑/❑	
7.	Does the producer have a properly equipped space for collecting waste and rejected crops?	❑/❑	
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)			
Item	**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 conducive to the survival of natural enemies of harmful organisms (other than those required in the list of mandatory activities and treatments)?	❑/❑	
Total points			

15. FURTHER READING

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