CHIEF INSPECTORATE OF PLANT AND SEED PROTECTION

Integrated Production Methodology of winter and spring triticale (*xTriticosecale*)

(first edition)

DRAFT

Approved
pursuant to Article 57(2)(2) of the Act on Plant Protection Products of 8 March 2013
(Journal of Laws 2020, item 2097, as amended)

by

the Main Inspector of Plant Health and Seed Inspection

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INTEGRATED PRODUCTION
OFFICIALLY CONTROLLED

Approved by
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Contents

1. INTRODUCTION

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

2. LEGAL PROVISIONS APPLICABLE IN INTEGRATED PRODUCTION (IP) AND RULES FOR ITS CERTIFICATION

2.1. Integrated Plant Protection as the foundation of integrated production (IP)

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

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

Professional users who use plant protection products are obliged to take into account the requirements of integrated plant protection set out in Regulation of the Minister for

Agriculture and Rural Development of 18 April 2013 on the requirements for integrated plant protection (Journal of Laws of 2013, item 505). According to the aforementioned Regulation, an agricultural producer should use all available measures and methods of protection against pests before applying chemical plant protection to reduce the use of pesticides. The provisions of this Regulation put a strong emphasis on, inter alia, the use of crop rotation, suitable varieties, compliance with optimal deadlines, use of appropriate agrotechnology, fertilisation, and prevention of the spread of harmful organisms. One of the requirements is also the protection of beneficial organisms and the creation of favourable conditions for their occurrence, in particular pollinating insects and natural enemies of harmful organisms. The use of chemical plant protection should be preceded by monitoring activities and supported by appropriate scientific instruments and advice.

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

The list of plant protection products authorised in Poland is published in the relevant register. Information on the scope of application of pesticides in individual crops is included on the labels. The Ministry of Agriculture and Rural Development provides a register and labels at https://www.gov.pl/web/rolnictwo/ochrona-roslin.

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

Before the application of a plant protection product, it is the responsibility of each user to read and follow the label.

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

ground equipment at a distance of at least 20 m from the apiaries;

field sprayers at a distance of at least 3 m from the edge of the roadway of public roads, excluding public roads falling within the category of municipal and district roads;

field sprayers at a distance of at least 1 m from reservoirs and watercourses and non-agricultural areas other than those treated with plant protection products.

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

In accordance with the legislation in force, any use of a plant protection product must be registered. The professional user is obliged to maintain and store for three years a dossier containing the name of the plant protection product, the time of use and the dose applied, the area or surface area or unit of weight of the grain and cultivation or the facilities on which the plant protection product has been applied. The law also requires the method of fulfilling the requirements of integrated plant protection to be indicated in the documentation by providing at least the reason for the treatment with a plant protection product. Filling the mandatory IP notepad in the system of integrated plant production fulfils the requirement to keep the above-mentioned documentation for certified crops.

For treatment with plant protection products, equipment intended for that purpose shall be used which, when used for its intended purpose, does not pose a risk to human health, animal health or the environment and is technically efficient and calibrated to ensure the correct use of plant protection products. Owners of equipment for the use of plant protection products are obliged to carry out periodic tests confirming technical fitness. The first inspection of new equipment is conducted no later than after 5 years from the date of its purchase. Tractor and self-propelled field sprayers shall be inspected at intervals of no more than 3 years. Manual and backpack sprayers whose tank capacity does not exceed 30 litres are excluded from the test obligation.

2.2. Integrated plant production in legislation

In the IPM certification scheme, all legal requirements for plant protection products must be respected, with particular regard to the principles of IPM.

2.3. Principles of certification

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

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

Training in integrated plant production is widely available, and individuals who have acquired the relevant knowledge in course of their education (as confirmed by a secondary school or a university) are exempted from the obligation to complete the basic training.

After the notification, the agricultural producer is obliged to grow according to the method of integrated plant production for the notified plant and to document activities in the IP notebook in detail. Model notebooks are included in the Regulation of the Minister for Agriculture and Rural Development of 24 June 2013 on documenting activities related to integrated plant production.

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

- completion of IP training;
- production in accordance with the methodologies approved by the Chief Inspector of Plant Health and Seed Inspection;
- fertilisation;
- documentation;

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

The maximum permitted plant protection product residue content and nitrate, nitrite and heavy metal levels in plants are tested in the plants or plant products of no less than 20 % of the growers listed in the grower register held by the certification body, starting with any growers suspected of not following integrated plant production principles. The tests shall be carried out in laboratories accredited in the relevant area.

A certificate issued at the request of the grower attests that integrated plant production principles are followed. The producer shall be certified if it has complied with the following requirements:

- has completed training in integrated plant production and holds a certificate of completion of that training, subject to Article 64(4), (5), (7) and (8) of the Plant Protection Products Act;
- conducts production and protection of plants according to detailed methodologies approved by the Chief Inspector and made available on the website managed by the Chief Inspectorate of Plant Health and Seed Inspection;
- uses fertilisation based on the actual demand of plants for nutrients, determined in particular on the basis of soil or plant analyses;
- documents the correct conduct of activities related to integrated plant production;
- complies with hygiene and sanitary rules with respect to the production of plants, in particular those specified in the methodologies;
- in plant and plant product samples collected for testing, no maximum permissible residues of plant protection products and levels of nitrates, nitrites and heavy metals have been exceeded;
- plant protection requirements relating to harmful organisms, in particular those specified in the methodologies, have been met.

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

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

3. CLIMATE AND SOIL REQUIREMENTS, AND SITE SELECTION

3.1. Site

The climatic conditions of Poland allow the cultivation of winter and spring triticale throughout the country. Some varieties show suitability for cultivation in all regions of Poland, while others may pose a risk for cultivation in specific areas, yielding worse or variably over the years, due to insufficient frost resistance, susceptibility to diseases, lodging, tolerance to soil acidification, etc.

Variable habitat conditions in the country are therefore a precondition for the regionalisation of varieties, which is currently being developed by the Post-Registration Variety Testing (COBORU).

One of the most important features of winter wheat is the degree of frost resistance which determines the geographical extent of the cultivation of the variety concerned. In the selection, there are varieties with frost resistance ranging from 3 to 6.0. The assessment of frost resistance (4.5 and above) allows for a wide range of cultivation covering basically the entire territory of the country.

The choice of site has a significant impact on the yield level of winter and spring triticale. The highest yield is given by winter triticale grown in crop rotation with 50 % cereals, lower with 75 %, and the lowest with a 100 % share of cereals (Jaśkiewicz 2020). Increasing the share of cereals in rotation to 75 % reduces the yield of spring triticale by about 12 %, and short-term cereal monoculture reduces yield by 18-20 % compared to a 50 % share of cereals in crop rotation. After legumes, the increase in yield can reach up to 20 % (Koc and Domska 1993). The value of the cereal stand should be improved by growing catch crops, mainly of the cruciferous family or mixtures with legumes for incorporating. A successful catch crop will increase the yield of spring triticale by 5-10 % (Jaśkiewicz and Brzóska 2011).

The sowing of triticale in cereal monoculture should therefore be avoided in a system of integrated plant production.

3.2. Soil

The most suitable conditions for the growth and development of winter triticale are found on very good and good wheat and rye soils with a slightly acidic or near-neutral pH (Jaśkiewicz 2014; Noworolnik and Jaśkiewicz 2018).

On the soils of the poor rye complex, high triticale yields can be expected only under conditions of high land cultivation and after good preceding crops (non-cereal). Winter triticale has a well-developed root system, which allows it to utilise post-winter water reserves, enabling it to tolerate periodic droughts well (Dmowski et al. 2001). Studies by Smagacz (1997) and Smagacz and Kusia (2010) show that winter triticale on very good rye soils is a competitive cereal compared to wheat, rye, and barley. Sown after field pea, as well as after cereal crops (after spring barley, winter triticale), it yields about 11-13 % higher than rye grown in similar sites (Smagacz 1997).-

On the soils of the good rye complex, triticale yields about 12 % less grain than rye. On the other hand, it yields higher than wheat (by 14 % on average) and winter barley (by 26 % on average). On the soils of the weak rye complex, the predominance of rye over triticale is greatest. On these soils, the yield of wheat and winter barley is similar and about 25 % lower than that of triticale. After a good preceding crop (after potatoes), the triticale yield is similar to that of winter wheat (Smagacz and Dworakowski 2004).

The response of triticale to soil quality is related to the characteristics of the varieties. Varieties with the dominance of rye genes have lower soil requirements. Greater tolerance of varieties to deteriorating soil conditions is usually generated by a larger root system, better ability of roots to take up hard-to-reach minerals, as well as greater resistance of plants to lodging (Budzyński and Szempliński 2003).

Studies by Noworolnik and Jaśkiewicz (2018) indicate a different response of winter triticale varieties to soil conditions and soil pH. Yield reductions for triticale varieties grown in poorer soil conditions are uneven. The reaction of winter triticale varieties to cultivation on soils of inferior bonitation classes, expressed in grain yield, is similar to the reaction of these varieties to gradually weaker soil and agricultural complexes.

Soil pH is also an important factor in determining the yield of winter triticale. Previous studies have found that the negative reaction of winter triticale to lower soil pH is stronger than that of rye (Noworolnik 2009). The susceptibility of winter triticale plants to lodging depends mainly on the properties of the varieties, and to a lesser extent on the quality of the soil (Noworolnik and Jaśkiewicz 2018). In poorer soil conditions, the susceptibility of plants to lodging is lower.

Spring triticale should be cultivated on soils of a very good rye complex and a good rye complex (Jaśkiewicz and Brzóska 2011; Nieróbca 2002). It is also possible to cultivate it on soils of a weak rye complex, provided that these soils are in good condition.

3.3. Preceding crop

Winter triticale has quite high preceding crop requirements, due to its significant susceptibility to diseases of the stem base and root system. In addition, the need to sow by the end of September, or possibly in the first ten days of October, creates significant requirements regarding the site and suitability of various plants as preceding crops. Individual crops may, in terms of their preceding crop value for triticale, be classified in the following groups:

- **good preceding crops**: legumes, rapeseed, early and medium potato;
- **medium preceding crops**: oats, silage maize, small-seeded legumes with grasses;
- **poor preceding crops**: wheat, triticale, barley, rye.

The worst preceding crops for winter triticale are cereals, with the exception of oats. They may not be used in the IP system in the preceding crop. The preceding crop value of leguminous plants lies in enriching the soil with nitrogen through symbiosis with bacteria capable of fixing atmospheric nitrogen and leaving a large mass of post-harvest residues. Small-seeded legumes and their mixtures with grasses, i.e. clover and alfalfa, are good preceding crops only when they are not strongly weed-infested and have provided a high yield. These plants consume a lot of water; therefore, in years with low summer rainfall, their value as a preceding crop for triticale decreases (Jaśkiewicz 2020).

The best preceding crops for **spring triticale** are root crops: beet, potato, oilseeds, and large-seeded legumes. **The worst preceding crops for spring triticale are cereals except**

oats. They may not be used in the IP system in the preceding crop. Maize has a medium value as a preceding crop for this form.

4. SELECTION OF TRITICALE VARIETIES IN INTEGRATED PRODUCTION

Choosing the right variety is one of the most important factors in integrated production. Therefore, when choosing a variety for sowing, it is worth analysing the results of COBORU to select the best variety that will provide the highest yield under given climatic and soil conditions (https://www.coboru.gov.pl/pdo/ipr).

Triticale (×*Triticosecale* Wittmack) is the youngest grain, and its history dates back less than 150 years. It is grown in 36 countries, but Poland is the largest producer of this species in the world (32 % of global production). Triticale is an intergeneric hybrid obtained from the crossing of wheat and rye; its uniqueness is due to having the best characteristics of the parental forms and reducing the defects of these species. This cereal has both spring and winter forms, with the winter form being more popular and with an annual cultivation area of over 1 million hectares, while spring triticale is grown on an area of over 50,000 hectares.

Polish triticale varieties still set standards in international breeding, in particular on European markets. Triticale in Poland ranks second in the structure of cereal sowing, after wheat. It owes its popularity to its high yield potential, being a cheap and good feed for animals (especially pigs and poultry), characterized by a high protein content, a high coefficient of digestibility, and a low content of anti-nutritional substances. The advantage of triticale is also lower soil requirements and tolerance to low soil pH. The winter form of triticale makes good use of the reserves of post-winter water from the soil, thus demonstrating a high tolerance to spring drought.

The production potential of triticale lies in its competitiveness compared to the cultivation of other cereals, particularly on poorer soils, and its suitability for low-input technologies. Triticale can also be grown for its environmental benefits. It has the ability to capture nutrients from the soil and limit their leaching into groundwater. It also plays an important role as a crop rotation plant, particularly in reducing the occurrence of soil pests (e.g. nematodes).

The agronomic advantages and improved performance of triticale grains compared to wheat obtained through research and development efforts make triticale an attractive option for increasing global food production, especially under stressful growth conditions. High resistance to stress in relation to environmental conditions allows adaptation to a given country, which translates into high grain yields.

Appropriate selection of varieties and the use of certified seed may determine the success of cultivation, as well as allow for a reduction in inputs into production. Research conducted as part of the Post-Registration Variety Testing (PDO) enables the assessment of the yield and economic value of available varieties. The conditions for conducting experiments are similar to the requirements of integrated agriculture, and the results obtained for individual varieties can definitely be valuable information for farmers who want to manage in this system.

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

5. PRE-SOWING TILLAGE AND SOWING

5.1. Soil cultivation

Winter triticale

Rational tillage should ensure optimal structure and density of soil, affect biological activity, help accumulation of water in soil, limit the amount of weeds and self-seeders, enable appropriate mixing of post-harvest residue of the preceding crop, organic and mineral fertilisers, create conditions for rapid and even emergence of plants and limit the severity of water and wind erosion. It is, therefore, one of the factors directly affecting the growth and development of the plant, and thus the size of the crop. The high costs of tillage cultivation, care for soil quality, and significant technical progress in agriculture related to the introduction of new-generation machinery and tools into production were the reasons for changes in the preparation of the soil for sowing, including the introduction of cultivation simplifications.

By simplifying the cultivation of the soil, the stability of the soil structure is improved, water infiltration and soil ventilation are increased (Smagacz 2016). The method of cultivation involving direct sowing in triticale negatively affects its yield (Małecka and Blecharczyk 2002; Starczewski et al. 2006). In the case of simplifications involving the omission of ploughing (Jaśkiewicz 2016), the influence of the variety and weather conditions was found. In dry years, when the total precipitation is below the multi-year average, triticale performs better in simplified cultivation, as post-harvest residues prevent water evaporation from the soil and provide plants with better moisture conditions. In the years when precipitation is close to the multi-year average under ploughing conditions compared to simplified cultivation, a 0.6 T/ha (8 percent) higher yield of winter triticale grain was obtained.

Spring triticale requires careful cultivation of the land. Good soil conditioning promotes the growth and development of plants and enables the utilisation of fertiliser components, which translates into the level of yield. Cultivation of the soil depends on the length of time that elapses from the harvest of the preceding crop to the onset of winter. The first treatment should be shallow cultivated ploughing or the use of a combined cultivator, which consists of a cultivator, levelling discs, and a string roller. In the absence of a combined cultivator, it is possible to use a stubble cultivator or a disc harrow. This treatment should be carried out immediately after harvesting the preceding crop to a depth of 6-9 cm. Deeper tillage of 10-12 cm should be performed when there is a need to expose weed stolons, dry them, and remove them with the spring tines of the cultivator. The purpose of these treatments is to stop the evaporation of water from the soil, cover organic fertilisers, post-harvest residues, and destroy self-seeding and emerging weeds (Budzyński and Szempliński 2003). In the simplified version of tillage, discing can also be used, which mixes post-harvest residues with the soil, facilitates the germination of volunteer plants and weeds, and accelerates the decomposition of post-harvest residues. An alternative to post-harvest cultivation is the cultivation of stubble catch crops (white mustard, oil radish, rapeseed or phacelia). However, it is only possible if the preceding crop harvest was not too delayed and the soil has adequate moisture.

The next procedure is to perform pre-winter ploughing in October or November. It is made to a depth of 18-22 cm and left in a sharp furrow. It loosens the soil, increases its porosity, and promotes the formation of a granular soil structure. After the potato, a large mass of haulm remains, which should be carefully covered by furrows. Cultivation after potatoes in a simplified version involves breaking up the soil layer using a grubber or shallow subsoiler without inverting the soil (Budzyński and Szempliński 2003). Such loosened soil retains water well and does not destroy soil microorganisms.

After clover and other perennial fodder crops, a combined cultivator or disc harrowing should be used to destroy the turf, followed by pre-winter ploughing with precise turning of the furrow to a depth of 25–30 cm.

Conventional tillage involving the use of a plough is the most energy-intensive and labour-intensive element of agrotechnics, which is why it is currently being modified to reduce the outlays. Studies carried out at the Institute of Soil Science and Plant Cultivation – National Research Institute in Puławy show that simplified cultivation results in a small reduction in the yield of spring triticale grain.

Spring cultivation should be started as early as possible, when the tools will not deteriorate the soil structure. The most important task of spring tillage is to retain in the soil as much water as possible from winter precipitation, accelerate the warming of the soil, and achieve the correct, granular structure of the top layer of the soil. This is achieved by isolating the soil surface from the deeper layers, which interrupts evaporation and accelerates the heating of the soil. Spring soil preparation for sowing should be carried out as quickly as possible, with a minimum number of tillage operations and a limited number of passes by machinery, as each pass leaves additional ruts and causes soil compaction and destruction of the soil structure, resulting in uneven emergence conditions. The first treatment on compact soils should be harrowing or rolling. For pre-sowing cultivation for spring triticale, passive and active cultivators are used. A passive set is a combination of a row seeder with a cultivator equipped with a string roller in the front part and a crushing roller in the rear part. During operation, the cultivator's teeth vibrate and cause fragmentation of soil clods, ensuring good preparation of the soil for sowing. On the other hand, the harrow behind the seed drill ensures good coverage of the seed material. Another seed drill is a row seeder with an active harrow and a toothed or string roller. The active harrow breaks up clods formed after the surface layer has dried, as well as loosens and levels the field surface, allowing the seed to be placed at a similar depth, ensuring uniform emergence (Małecka 2006). Spring ploughing for spring triticale is an unacceptable procedure, as it causes a significant decrease in yield.

In the integrated production of triticale, an important role is attributed to the biological activity of the soil and its natural fertility, so ploughing should be done once every three years. Ploughing reduces the number and activity of microorganisms, and a fairly long period of time must pass, called the recovery period, for the biotic relations in the soil to return to normal. For the next two years, ploughing should be replaced with tools that loosen the soil, without inverting it (e.g. heavy grubbers). The size of the cultivator used depends on the area of the field and its availability on the agricultural holding. Cultivators ensure even mixing of post-harvest residues, levelling, and secondary compaction of the soil.

5.2. Sowing

An important element of integrated triticale production technology is correct sowing, which consists of the appropriate seed, the sowing date, and the sowing quantity. It determines the basic elements of the yield, i.e. the number of ears per unit area, the number of grains in the ear. For sowing, treated certified material must be used, which guarantees varietal purity and the appropriate quality of the seed. Treated certified seed perfectly fits into the integrated protection of triticale.

In the integrated production of winter and spring triticale, the use of certified and treated seed in accordance with the ESTA standard or an equivalent standard is required.

Date of sowing is considered to be one of the most important crop-forming factors. Its action directly affects the growth and development of the cereal plant and, consequently, the level of yield. The variation in the date of sowing is closely related to the change in the length of the day and air temperature during the initial development of plants.

Due to the significant variation in weather conditions during the autumn season across different regions of the country, the optimal sowing periods for winter triticale vary:

- in the north-eastern and eastern parts, they fall between 10 and 25 September,
- in the central and south-central parts from 15 to 25 September,
- in the west and north-west from 20 September to 5 October.

Spring triticale

In conditions of a short day with low temperatures, spring species propagate well. Sowing at a higher temperature and with a longer day shortens the propagation stage, which is why,

often with late sowing, plants quickly reach the stem elongation stage, limiting the number of ears per unit area.
Compliance with the sowing time is considered one of the basic agrotechnical procedures of integrated production. Sowing of spring triticale should be carried out as early as possible, when the condition of the soil allows. This allows the plants to develop a stronger root system. It also allows for more intensive uptake of nutrients and the use of water reserves from deeper layers of the soil. The early date of sowing, combined with good soil conditions, promotes the production of more vegetative mass of cereals which brings about the threat of lodging. In this case, it is important to choose a variety resistant to lodging.

Sowing density

One of the most important elements of integrated cereal production technology is to ensure the optimal number of ears per unit area. Proper selection of sowing density, which is associated with the number of ears per unit area, is very important for good yields of winter triticale. Initially, any increase in the number of ears leads to an increase in yield levels; subsequently, further increases do not affect yield, and additional increases result in a decrease (Jaśkiewicz 2009). This development of the yield level is related to the change in light and nutritional conditions and the competitive interaction of plants and shoots on each other (Jaśkiewicz and Mazurek 1997). The density of plants per unit area affects the structure of the crop through changes in plant height and productive tillering (Jaśkiewicz 2008). In parallel with the increase in plant density, the proportion of plants with shortened shoots, characterized by a smaller number of grains per ear and a lower weight of individual grains compared to tall plants, increases. This initially leads to a reduction in the beneficial effect on ear yield, followed by the disappearance of this effect and a decrease in yield per unit area. Seeding standards for winter triticale are given in Table 1.

Table 1. Standards for sowing winter triticale – million seeds/ha

Soil complex	Sowing standard
Wheat	250 (105)[1/] – 300(126)[1/]
Rye very good	300(126) – 400(186)
Rye good	400(168) – 500(210)

[1/] – The approximate sowing in kg/ha (with TGW 40 g, germination capacity 95 %) is indicated in brackets. Source: Jaśkiewicz (2014)

Varieties of individual species, due to unequal tolerance to mutual shading of plants, ability to propagate, and different resistance to lodging, differ in the requirements for the sowing standard. Varieties with smaller, larger, or intermediate light requirements can be distinguished, and thus should be sown more or less densely:

- rare sowing (250-300 grains per m^2) is required in case of: Orinoko, Kasyno, Rotondo, Twingo, Tomko, Corado, Dolindo, Metro, Panaso, Stelvio, Tributo;

- average sowing (300-360 grains m^2) is required in case of: Porto, Octavio, Camelo, Meloman, Sekret, Panteon, Trefl, Avokado, Salto, Wiarus, Trapero, Maestro, Gringo, Silverado, Pizarro, Balcanto, Dinaro, Mondeo, Polo, Tiesto;
- larger sowing (320-380 grains per m^2) is required in case of: Toledo, Preludio, Fredro, Grenado, Trismart.

On fertile soils well supplied with nutrients and water, there is strong plant tillering and lush growth. Excessive densification of the field and its poor ventilation promotes the worsening of triticale infestation by diseases that, along with lodging, contribute to significant losses of grain yield. Therefore, the need for less frequent sowing is justified. When growing cereals in a stand following legumes that increase the soil's nitrogen content, which enhances plant tillering, it is recommended to reduce the sowing rate.

The application of the appropriate sowing rate for winter triticale depends on the habitat and agrotechnical conditions (table 2).

Table 2. Range of increasing (+ %) or decreasing (- %) the sowing standard of winter triticale depending on different conditions and factors

Site and agrotechnical conditions	Winter triticale
Acidic soil reaction	+ (2–4 %)
Delayed sowing date	+ (3–6 %)
Strong weed infestation of the field	+ (3–5 %)
Not very careful cultivation of the field	+ (2–4 %)
Strongly tillering varieties	- (30–40 %)[1/]
Poorly tillering varieties	+ (4–7 %)
Major intensity of diseases in the area	- (2–3 %)
Region with a climate conducive to plant lodging	- (4–6 %)

[1/] short-stemmed (semi-dwarf) varieties

Source: Noworolnik (2015)

Sowing should be carried out at a depth of 2-4 cm, depending on the humidity and the soil compactness. For the proper development of plants, the uniformity of sowing and the greatest possible distance of grains from each other in a row are very important, which can be achieved according to the principle: the higher the density, the smaller the spacing should be. Hence, a row spacing of 10–11 cm is most commonly used.

The tested varieties of spring triticale have similar requirements as regards sowing density (Jaśkiewicz and Brzóska 2011; 2004) (table 3).

Table 3. Recommended sowing quantities of spring triticale in million grains/ha and kg/ha

Soil complex	Sowing standard
Wheat	4.5 (193)* – 5.0 (215)*
Rye very good	5.0 (215) – 5.5 (236)

Rye good	5.5 (236) – 6.0 (257)

*– for TGW – 40 g, seed germination capacity 95 % and purity 98 %.

Under the conditions of proper agrotechnics, the number of plants per 1 m² after emergence in relation to the sown grains should be 90–95 %. In the tillering stage, the optimal plant density is 450–540 plants per 1 m². Self-regulation processes occurring in the crop cause the number of plants per 1 m² in the stem elongation stage to decrease. High grain yield can be obtained from a crop with a density of 450–500 ears per 1 m². This density also ensures good productivity of the ear (27-30 grains per ear, 39-40 g TGW). The average yield per hectare is 4.5–5.5 T/ha for grain and 4.0–4.5 T/ha for straw (Nieróbca 2002).
The application of the appropriate sowing rate for spring triticale depends on the habitat and agrotechnical conditions (table 4).

Table 4. Range of increasing (+ %) or decreasing (- %) the sowing standard for spring triticale depending on various conditions and factors

Site and agrotechnical conditions	Spring triticale
Acidic soil reaction	+ (3 – 4 %)
Delayed sowing date	+ (7 – 15 %)
Not very careful cultivation of the field	+ (3 – 4 %)
Strong weed infestation of the field	+ (4 – 5 %)
Not very careful cultivation of the field	+ (2 – 4 %)
Major intensity of diseases in the area	- (2 – 4 %)
Region with a climate conducive to plant lodging	- (3 – 4 %)

Source: Noworolnik (2015)

6. SUSTAINABLE TRITICALE 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 (and confirmed by documents).

Fertilisation in the integrated production of triticale is aimed at meeting the nutritional needs of plants at a level that allows for achieving the expected grain yield of good quality and reducing the threats to the natural environment caused by the movement of nutrients from the soil to groundwater. The integrated fertilisation system is based on a nutrient balance, taking into account the uptake of nutrients by plants from all sources (soil, preceding crops, mineral fertilisers, organic fertilisers) and their inflow from natural and mineral fertilisers (Igras and Rutkowska 2009). Mineral nutrients should be utilised to the maximum extent by plants, as unused ones are subject to losses due to leaching, water and wind erosion, or volatilization of gaseous forms, which causes pollution of water and soil and reduces the profitability of fertilisation. The reasons for the poor use of nutrients by plants are numerous. The most important include: unregulated soil pH, excessive application of fertilisers, inappropriate timing or techniques of fertiliser application.

The integrated fertilisation system should be based on a decision support system that includes both conventional fertiliser consultancy (e.g. the NawSald computer advisory program) as well as operational consultancy based on current observation of the stand. The basis for fertiliser advice is the physicochemical assessment of the soil: abundance of phosphorus, potassium, magnesium and micronutrients and soil reaction (Igras and Rutkowska 2009). The operational advice is based on soil tests, which provide the basic information for the farmer to assess the current potential of the soil to nourish the plant with one or more elements. Control tools used during the growing season should be plant tests, providing information on the nutritional status of the currently cultivated plant. The information obtained from the soil test is used on the holding to make decisions at the strategic and operational levels, and from plant tests only at the operational level (Grzebisz 2017). **Therefore, at intervals of no more than 4 years, analyses of the content of individual nutrients in the soil should be carried out.** This frequency of analysis is in principle sufficient for all nutrients except nitrogen. Nitrogen is a mobile nutrient, and the assessment of the needs for its application in a given field should be based on systematic soil and plant analyses.

Rational mineral fertilisation of triticale in integrated technology involves:

- determination of the fertiliser dose taking into account the nutrient abundance of soils (NPK, Mg), pH, quality and type of soil, variety, expected yield, preceding crop, weather, etc.;
- using the latest methods (content of N_{min}, plant analysis, chemical or colour test) in determining nitrogen needs and doses and the timing of their application;
- the application of nitrogen fertilisers in split doses, adapted to the rhythm of nitrogen uptake by cereals.

The most important step is to determine **the nutritional requirements** of plants. This is the amount of nutrients, mainly nitrogen, phosphorus, and potassium, that plants theoretically absorb with the crop yield. Nutritional requirements can be regarded as a need for fertilising components. Table 5 shows the amounts of nitrogen, phosphorus, and potassium absorbed by triticale to produce 1 T of yield. Thus, the nutrient demand is calculated by multiplying the potential yield achievable under farm conditions by the uptake of N, P, K, Mg. The food requirements of triticale are slightly different from those of other cereals. They are intermediate between the requirements of wheat and rye. Compared to wheat, both winter and spring triticale require more potassium and less nitrogen to produce 1 ton of grain.

Table 5. Mineral uptake in kg t^{-1} of grain with straw

Grain species	Nitrogen nitrogen	Phosphorus (P_2O_5)	Potassium (K_2O)	Magnesium (Mg)	Calcium (CaO)
Winter wheat	23.0	10.0	20.0	5.0	5.0
Spring wheat	21.0	12.0	34.0	5.0	6.0
Rye	21.0	11.0	27.0	5.0	6.0
Winter barley	23.0	10.0	25.0	4.0	10.0
Spring barley	22.0	10.0	24.0	5.0	9.9
Winter triticale	22.0	10.0	24.0	5.0	8.0
Oat	24.0	12.0	36.0	7.0	11.0

Source: Czuba 2000

One of the basic conditions for effective nitrogen-to-harvest processing is to maintain an appropriate N:P:K ratio, which should be as follows: 1:0,4:1. The demand for micronutrients (boron, copper, molybdenum, zinc and iron) is relatively small. Triticale extracts from 1 ha 30-40 kg of sulphur (S), 7-10 kg of sodium (Na) and micronutrients 120 g of copper (Cu), 500 g of manganese (Mn), 350 g of zinc (Zn), 115 g of boron (B) and 7 g of molybdenum (Mo). Micronutrients regulate biochemical processes occurring in plants, allow for better use of macronutrients, and also limit the development of fungal diseases. They are supplied to plants in the form of foliar spraying, as they are poorly absorbed by the root system. They can be used together with pesticides, thus reducing the costs of the treatment (Kościelniak and Dreczka 2009). Table 6 provides recommended doses of mineral fertilisers (kg/ha) depending on the expected yield.

Table 6. Recommended mineral fertiliser doses (kg/ha) depending on the expected yield

Yield in T/ha	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Magnesium (MgO)
6	80	60	85	10
7	100	70	100	10
9	120	90	125	15
10	140	100	130	20

Source: Jadczyszyn et al. (2012)

Liming and magnesium fertilisation

The pH analysis of the soil should be carried out before each planned liming of the soil. **Soil pH analyses should be carried out at intervals of up to 4 years.**

The precondition for good crop yields and effective use of fertiliser nutrients is optimal soil pH. Soil acidification is a continuous process facilitated by the use of acidifying mineral fertilisers. Triticale is less sensitive to the acidic reaction of the soil than wheat or barley, but reacts positively to the liming of acidic soils. In acidic soils, the risk of triticale dying out is much greater than in slightly acidic or neutral soils, because in such conditions there is a weaker development of the root system and whole plants and their shallow rooting, which consequently leads to the inability to take up mainly calcium and magnesium in the amount necessary for proper nitrogen management. Acidification of soils reduces the efficiency of nitrogen and phosphorus use, increases gaseous nitrogen losses from fertilisers, and leads to the accumulation of aluminium, manganese, and heavy metals in the soil (Grzebisz et al. 2013; Ochal and Kopiński 2017). The optimum soil pH for winter triticale is between 5.5 and 6.5 in KCl. Soils with a lower pH need liming. Soil pH analyses should be carried out at intervals of up to 4 years.

Liming is an important treatment affecting the physical, physicochemical, and biological properties of the soil. It promotes increased microbiological activity in the soil environment, activates mineralisation processes, and enhances the availability and efficiency of certain mineral nutrients. It is best to apply lime under the preceding crops or directly under triticale, but only after preceding crops that leave the field early. The lime should be spread on the stubble before the post-harvest cultivation is carried out.

Doses of lime depend on the degree of acidification and the agronomic category of the soil (table 7). The liming of very acidic and acidic soils should be divided into two stages: in the first, apply two-thirds of the required dose and after a year, test the pH. The correct choice of fertiliser is crucial for effective liming. Oxide lime should be applied to heavy clay soils, and carbonate lime to light and sandy soils. The date of liming should take into account the reaction of calcium fertilisers with other fertilisers that may lead to nutrient losses. Nitrogen ammonium fertilisers and phosphate fertilisers should not be applied immediately after and before liming. The interval between treatments should be at least 4 to 6 weeks.

Table 7. Calcium doses (in T CaO/ha) for triticale depending on soil compactness and pH

Liming	Soil					
	light		medium		heavy	
	pH	CaO dose	pH	dose CaO	pH	CaO dose
Necessary	up to 4.5	3.5	up to 5.0	4.5	up to 5.5	6.0
Needed	4.6-5.0	2.5	5.1-5.5	3.0	5.6-6.0	3.0
Recommended	5.1-5.5	1.5	5.6-6.0	1.7	6.1-6.5	2.0
Limited	5.6-6.0	-	6.1-6.5	1.0	6.6-7.0	1.0
Unnecessary	above 6.0	-	-	-	-	-

Source: Jaśkiewicz et al. (2009)

Magnesium fertilisation is most often combined with liming, as acidified soils are frequently characterized by low or very low magnesium content. In the wide range of lime fertilisers, a significant proportion contains magnesium. On soils with very low magnesium content, half of the recommended dose of CaO should be in the form of magnesium lime, while on soils with low Mg content, one third of the recommended dose of CaO should be used.

On soils poor in magnesium but not requiring liming, 60-80 kg MgO/ha should be applied using magnesium fertilisers (kieserite, kainite, sulfate of potash magnesia, rolmag).

Fertilisation with phosphorus and potassium

Phosphorus in the plant plays a significant role, influencing root growth, stimulating the uptake of other nutrients, increasing nitrogen and exogenous amino acids, enhancing the plant's resistance to stress and diseases, and affecting the number of grains in the ear. Phosphorus is absorbed from the soil solution in the form of ions. Winter triticale has a high demand for phosphorus during the initial growth stage, the resumption of vegetation in the spring, and grain setting.

Potassium performs many physiological functions. It is primarily responsible for: the growth of meristematic cells, the regulation of stomatal function, the activation of enzymes, and the transport of mineral and organic compounds in roots and aerial parts.

Triticale well supplied with potassium uses less water to produce a unit of dry matter. Potassium positively affects the increase of resistance of plants to low temperatures; therefore, plants well supplied with potassium overwinter better. Plants take up potassium ions K^+ from the soil solution or the soil sorption complex. This element is easily leached from light soils; on heavier soils, the leaching of potassium is more difficult, but it can undergo fixation.

The demand of triticale for phosphorus and potassium depends on the nutritional requirements of the plant and the fertility of the soil. On soils with high and very high content of P and K, the demand for nutrients is up to 50 % less than the nutritional needs. Under these conditions, plants use soil resources. On soils with low or very low P and K content, the demand for this nutrient can be up to 50 % higher than the nutritional needs of plants. This is because surplus ingredients are used to increase soil fertility. Therefore, P and K fertilisation needs = nutrient needs of plants x corrective coefficient (table 8).

Table 8. Corrective coefficient factor values

Soil content P and K				
Very low	Low	Medium	High	Very high
1.5	1.25	1	0.75	0.50

Source: Institute of Soil Science and Plant Cultivation – National Research Institute

As mentioned, the doses of P and K depend on the fertility of soils and the amount of yields obtained. Example doses of P and K are provided in the tables; they were calculated using the NawSald program (table 9). Registered varieties of spring triticale respond in a similar way to phosphorus and potassium fertilisation. Phosphorus and potassium fertilisers should be applied in the spring before sowing triticale. On compact soils, they can also be spread under the plough before winter ploughing.

Table 9. Examples of P and K doses for winter triticale on light soil after potatoes (yield 250 dt/ha, manure 30 T/ha, N–70 kg/ha fertilisation, P_2O_5–70 and K_2O–105 kg/ha)

Soil abundance in P and K	Grain yield in dt/ha			
	45		60	
	Doses in kg/ha			
	P_2O_5	K_2O	P_2O_5	K_2O
Low	61	110	81	146
Medium	48	95	65	127
High	36	81	48	108

Source: Institute of Soil Science and Plant Cultivation – National Research Institute

Depending on the availability of assimilable forms in the soil, phosphorus doses should be 60-100 kg P_2O_5, and potassium 80-120 kg K_2O per 1 ha. Only in very rich soils and with the uncertainty of obtaining a large yield, phosphorus doses can be reduced to 40-50 kg P_2O_5, and potassium to 60-70 kg K_2O per 1 ha (table 10).

Table 10. Doses of phosphorus and potassium fertilisers (in kg of pure nutrient per 1 ha) for spring triticale depending on yield level and soil abundance

Anticipated grain yield T per 1 ha	Contents of									
	phosphorus					potassium				
	very low	low	medium	high	very high	very low	low	medium	high	very high
up to 3.5	70	60	50	40	30	80	80	70	60	30
3.6 – 4.5	80	70	60	50	40	100	90	80	70	40
above 4.5	100	90	80	60	50	120	110	100	80	60

Source: Institute of Soil Science and Plant Cultivation – National Research Institute

Nitrogen fertilisation

Nitrogen is the most yield-producing nutrient. It affects the basic characteristics of the crop structure: the number of ears, the number of grains per ear, and the thousand grain weight (TGW). In addition, it stimulates the protein content in the grain. Nitrogen fertilisation is difficult, due to the lability of nitrogen and overfertilisation of plants. Triticale absorbs very large amounts of nitrogen to accumulate protein in the grain, especially in wet years, where nitrogen fertilisation increases the grain yield (Yang et al. 2000). An imbalance of nitrogen causes triticale to absorb it in excess, which may lead to over-densification of the crop, lodging, and consequently, a decrease in yield.

The supply of nitrogen should coincide with the growth and development of triticale and cover those stages where plants have the greatest demand.

The first step is to proceed with calculating dietary needs for nitrogen. This is the amount of nitrogen needed to produce a specific crop. All sources of nitrogen must be taken into account in integrated production. From the soil resources, 1-2 % of nitrogen is released into the soil solution; this amount is sufficient to produce a grain yield of 1-4 tons.

Date of nitrogen application

Autumn nitrogen fertilisation of winter triticale after non-cereal preceding crops is considered superfluous and is usually performed entirely in spring. Nitrogen should only be applied pre-sowing after cereal precursors at a dose of 20-30 kg N per hectare, preferably in the form of compound fertiliser. The reason for using nitrogen after cereal precursors is to leave post-harvest residues with a wide C:N ratio in the field. The carbon available in straw stimulates the development of microorganisms that use nitrogen from the soil and supplied in mineral fertilisers to build their bodies. Nitrogen should not be applied pre-sowing after non-cereal crops, as it can contribute to the lush development of triticale in autumn, worsen the wintering of plants, and harm the environment by leaching this element from the soil.

Nitrogen fertilisers should be applied in split doses, adapted to the rhythm of uptake of this nutrient by the plant. Doses up to 90 kg N ha^{-1} are applied in two parts, i.e. 40-60 % during the start of the growing season and the rest during the stem elongation stage. The higher doses should be applied in three stages, i.e. 40-50 % during the vegetation period, 30-35 % in the stem elongation stage, and 20-25 % in the flag leaf stage until the beginning of heading.

The first dose of nitrogen should supplement the soil resources; it is used to achieve the appropriate tillering and density of the crop (Jaśkiewicz 2009). In the case of late spring and poorly tillered crops, the dose should be relatively large, up to 60 kg ha^{-1}, to meet the needs of the fast-growing plant. A second dose of nitrogen should be applied at the beginning of the stem elongation stage. Nitrogen during this period affects weight gain, reduces the reduction of shoots produced, and determines the structure of the crop, including the number of ears and the number of caryopses per ear. The third dose of nitrogen is applied at the stage of the fully developed flag leaf or ear emergence. It affects the protein content and the thousand grains weight.

In integrated technology, it is very important to determine the size of individual nitrogen doses. Soil and plant tests are helpful in determining them.

The first dose shall be determined on the basis of mineral nitrogen (N_{min}), which indicates the content of nitrate and ammonium ions in a specific layer of the soil profile, usually up to a depth of 60 cm. The sum of mineral forms of nitrogen, expressed in kg ha^{-1}, is directly related to the nutritional needs of plants. For the purposes of consultancy, N_{min} content was determined depending on the agronomic category of soil (Table 11).

It is recommended to apply the first dose of nitrogen in a loose form. It can be calculated from the formula:

N dose in fertilisers = nutrient needs of plants – quantity of N found in soil

If the result of laboratory test N_{min} demonstrates a **high or very high content** of the nutrient in the soil to a depth of 60 cm, the planned dose of fertilisers should be reduced by the difference between the N_{min} content found in the soil taken from the field and the upper limit of the average content for such soil.

In the case of **very low or low content**, the recommended dose of N should be increased by the difference between the lower limit of the average content and the determined amount of N_{min} in the soil. E.g. from the N_{min} test, it appears that the average soil to a depth of 60 cm contains 115 kg of nitrogen per ha. In accordance with Table 10, the upper limit of N_{min} content for medium soil is 90 kg per ha. The calculation shows that the planned nitrogen dose for triticale should be reduced by 25 kg N/ha (115 - 90 kg N ha^{-1} = 25 kg).

If the content of N_{min} in light soil is 45 kg nitrogen per ha and the lower limit of the average content for light soil is 61 kg nitrogen per ha (61 - 45 kg N/ha = 16 kg N/ha), then the recommended nitrogen dose should be increased by 16 kg N/ha.

Table 11. Assessment of N_{min} content (kg/ha) in soil to a depth of 60 cm in spring

Soil agronomic category	N_{min} content				
	very low	low	medium	high	very high
Very light	up to 30	31-50	51-70	71-90	above 90
Light	up to 40	41-60	61-80	81-100	above 100
Medium and heavy	up to 50	51-70	71-90	91-100	above 100

Source: Jadczyszyn et al. (2012)

The need for the second and third doses should be based on observations of the nutritional status of the plants (fertiliser windows), chemical analysis of the plants or the Soil Plant Analysis Development (SPAD) index.

Plant tests are used to assess the nutritional status of plants with nitrogen during vegetation (Fotyma 2002). The basis of this method is the analysis of the entire aerial mass of the plant. Samples are taken between the tillering stage and the start of stem elongation, and the total nitrogen content is determined in the laboratory. The total nitrogen content changes with the age of the plant. Young plants in the tillering stage contain much more nitrogen than older plants in the heading stage with the same nutritional status. This is a generally known pattern that involves a decrease in nitrogen concentration in the dry matter of plants as they grow and develop. This is due to the phenomenon of 'nitrogen dilution' in the growing mass of the plant. This test must be carried out in a strictly defined development stage and used in practice relatively quickly. Table 12 presents the possibility of refining the second nitrogen dose based on the results of the plant analysis.

Table 12. Clarification of the second spring nitrogen dose based on the percentage of total nitrogen in the aerial parts of plants in the stem elongation stage

Fertilisation needs	Triticale	Modification of the second

		dose of nitrogen
Very small and small	> 4.3	do not use
Medium	3.9 – 4.3	decrease by 25-50 %
High	3.0 – 3.9	maintain
Very high.	< 3.0	increase by 25-50 %

Source: Institute of Soil Science and Plant Cultivation – National Research Institute

The state of nitrogen nutrition of plants in later developmental stages can be assessed more quickly on the basis of the SPAD test - the leaf greenness index. To perform such measurements in field conditions, a relatively simple optical instrument called an N-tester is used.

The second dose of nitrogen is applied depending on the plant's supply of this nutrient in the

period from the second node stage to the opening stage of the leaf sheath. It is a good solution to determine the mineral nitrogen content of the plant or to determine the state of leaf greenness (SPAD units) using the so-called N-Tester. Winter wheat plants well supplied with nitrogen have all the leaves intensely green, with the same shade of greenness. In case of deficiency, nitrogen moves from older to younger leaves. The assessment of the nitrogen supply of plants is best done by comparing the colour of the leaves in the flag leaf stage. When the third leaf is brighter than the second — the plant lacks nitrogen.

The yield level of **spring triticale** and the effectiveness of nitrogen fertilisation depend to a large extent on the course of the weather in a given year. If the weather favours good yields, there is also a better use of higher doses of nitrogen. Doses greater than 50 kg N per hectare should be applied in two installments. The first part, representing 50-60 % of the total dose, is applied before sowing triticale, for spring tillage, with the remaining part of the dose applied during the stem elongation stage. The response of triticale to nitrogen fertilisation depends on soil fertility, the preceding crop, and weather conditions. For average rainfall, appropriate tillage and optimal sowing times, the nitrogen doses given in Table 13 are recommended.

However, it should be emphasised that the fertilisation of triticale with nitrogen must remain an open matter. This means that the advisability of using nitrogen and the amount of the second part of its dose must be decided from time to time on the basis of an analysis of the weather, observations of plants in the field and, possibly, the results of determinations of the nitrogen content in plants. This is especially important in the case of lush plant growth, if the use of a retardant is not expected.

Table 13. Doses of nitrogen fertilisers (in kg of pure nutrient per 1 ha) for spring triticale depending on the expected yield and soil complex

Expected grain yield, T per 1 ha	Soil-agricultural complex		
	wheat very good and good,	rye very good	rye good

	wheat defective		
up to 3.5	70	80	90
3.6–4.5	80	90	100
above 4.5	90	100	110

Source: Jadczyszyn et al. (2012)

Sulphur fertilisation

It is worth ensuring sulphur fertilisation in conditions of low and very low content of this element in the soil. In this case, 35 to 50 kg S/ha should be used. Sulphur is most often used in the form of multi-nutrient fertilisers. However, when planning sulphur fertilisation, it should be remembered that significant amounts of this element accompany other nutrients in fertilisers (Jadczyszyn et al.). 2012).

Micronutrient fertilisation

Micronutrient fertilisation becomes significant under conditions of high triticale yield. On soils with a regulated pH, with optimal macronutrient nutrition of plants, micronutrient deficiency may become a factor limiting yield. It is then worth examining the content of micronutrients in soils, especially if organic fertilisation is not used on the holding. The need to use micronutrient fertilisers is determined by the abundance of soil. On soils with a high content of micronutrients, fertilisation with them is unnecessary. With low soil content, soil fertilisation with doses of micronutrients administered and foliar fertilisation (in particular of plants sensitive to shortages) is advisable (Kościelniak and Dreczka 2009; Jadczyszyn et al. 2012; Wojtkowiak 2014).

The integrated plant production system prohibits the use of sewage and digestate sludge and others of unknown composition for fertilising purposes due to the danger of introducing unmonitored hazardous substances into the secondary circulation, which can be accumulated in the process of their manufacture.

7. INTEGRATED PROTECTION AGAINST PESTS

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

Integrated plant protection includes all available actions and methods of protection against agrophages (weeds, diseases, pests) with preference given to the use of non-chemical measures and methods that reduce the harmfulness of agrophages, in particular:

- use of crop rotation, appropriate sowing dates and plant density;
- use of appropriate agro-techniques, including the application of mechanical plant protection;
- the adoption of appropriate measures and methods for the protection of plants against pests should be preceded by the monitoring of their presence and take into account current knowledge on the protection of plants against pests;
- the use of seed material produced and evaluated in accordance with seed legislation;
- application of fertilisation and liming, where appropriate;
- the use of hygiene measures (cleaning, disinfection) to prevent the occurrence and spread of pests;
- the protection of beneficial organisms and the creation of conditions conducive to their occurrence, in particular for pollinators and natural enemies of harmful organisms.

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

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

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

Plant protection products shall be used in accordance with the current triticale protection programme with the recommendations given on the label and in such a way as to avoid endangering human or animal health or the environment.

The list of plant protection products approved for sale and use in Poland is published in the register of authorised plant protection products. Information on the scope of application of pesticides in individual crops is included on the labels. The plant protection product search engine is a helpful tool when selecting pesticides. Current information on plant protection products use is available on the Ministry of Agriculture and Rural Development website at: https://www.gov.pl/web/rolnictwo/ochrona-roslin..

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

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

It should be borne in mind that the products included in the protection programme do not present a risk when properly applied in accordance with the approved labelling of the plant protection product. Compliance with the instructions for use, such as, among others, the appropriate choice of the product, the dose, the date of application, the appropriate stages of development of the crop and pests, the appropriate temperature-humidity conditions and the technical conditions for the performance of the treatment, have a decisive influence on the safety of treatments with plant protection products.

In order to perform laboratory diagnostics (usually in the case of determining the pathogens), tests are carried out in laboratories accredited to the appropriate extent in accordance with the provisions of the Conformity Assessment System Act of 30 August 2002 or the provisions of Regulation No 765/2008.

7.1. WEED INFESTATION CONTROL

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

The harmfulness of weeds depends on the agrotechnical treatments, the biology and rhythm of weed development, as well as the potential of the crop itself to compete with the weeds. Environmental conditions, including soil type, availability of nutrients, and the course of hydrothermal conditions during the vegetation period, also have an impact on the harmfulness of weeds (Krawczyk et al. 2015).

In the development of the crop, the so-called ‘critical period of weed competition’ can be distinguished when the crop is most susceptible to weeds. In winter triticale, this is usually the time interval from sowing to the end of the tillering stage (BBCH 29). However, in spring triticale, this is usually the time interval from sowing to the initial stages of stem elongation (BBCH 30).

In winter triticale, during the ‘critical period of weed competition’, monocot weeds, particularly species such as: loose silky-bent (*Apera spica-venti* (L.) P. Beauv.), slender meadow foxtail (*Alopecurus myosuroides* Huds.), brome (*Bromus* sp.), and in spring sowing: wild oat (*Avena fatua* L.) and wild oat (*A. sterilis* L.).

The various botanical forms and varieties of rye, due to the different morphological characteristics, show different potential in competing with weeds. Morphological characteristics that favour competitiveness vis-à-vis weeds include, in particular, initial vigour, growth (energy and germination capacity), productive tillering potential, foliage area and stem length. These features affect, among other things, the development and architecture of the field. In optimal conditions for development, strong vigour of plants, as well as dynamic growth and formation of a compact stand effectively limit the development of most weed species.

7.1.1. The most important weed species

In cereals, an increase in weed infestation of plantations is increasingly observed, while the spectrum of weeds is reduced in favour of compensating for the dominant species that are increasingly difficult to control on cereal plantations.

Among weeds, the greatest harm is displayed by species that are characterised by rapid development and high reproductive potential. The species composition of weeds and their quantity are mainly shaped by agrotechnical measures, especially weed control methods, but also by soil condition, including its physical properties, the amount of available humus or mineral components, and the soil pH.

In winter triticale, monocot weed species are an increasing problem, in particular: loose silky-bent (*A. spica-venti*), and locally also slender meadow foxtail (*A. myosuroides* Huds.), rye brome (*B. secalinus* L.) and under simplified cultivation conditions barren brome (*B. sterilis* L.) (table 14).

Of the dicot species on winter triticale plantations, the most common are species such as: field geranium (*Geranium pusillum* L.), field poppy (*Papaver rhoeas* L.), cornflower (*Centaurea cyanus* L.), field pansy (*Viola arvensis* Murray), speedwells, and chamomile and knotweed, and in spring triticale also lamb's quarters (*Chenopodium album* s.str. L.).

The large presence of weeds on weed-infested fields is due to their adaptability to habitat conditions, their high multiplication rate (i.e. they produce a very large number of seeds), and their ease of self-spreading.

Table 14. Occurrence and significance of selected weed species in triticale

Weeds	Winter triticale	Spring triticale
Geranium — *Geranium* L.	++	+
Wormwood — *Artemisia* L.	+	+
Cornflower — *Centaurea cyanus* L.	++	+
Cockspur grass – *Echinochloa crus-galli* (L.) P. Beauv.	-	+
Common fumitory — *Fumaria officinalis* L.	+	+
Field pansy — *Viola arvensis* Murray	++	++
Field mustard — *Sinapis arvensis* L.	-	+
Chickweed — *Stellaria media* agg	++	++
Dead-nettle — *Lamium* L.	+	+
Lamb's quarters — *Chenopodium album s.str.* L.	-	+++
Poppy — *Papaver* L. sp.	++	+
False mayweed — *Matricaria perforata* Merat.	++	++

Loose silky-bent — *Apera spica-venti* (L.) P. Beauv.	+++	+
Field forget-me-not — *Myosotis arvensis* (L) HILL	+	+
Creeping thistle — *Cirsium arvense* (L.) Scop.	+	+
Common wild oat — *Avena fatua* L.	+	+
Couch grass — *Elymus repens* (L.) Gould	++	++
Speedwell — *Veronica* L. sp.	++	+
Catchweed — *Galium aparine* L.	+	+
Wild buckwheat — *Fallopia convolvulus* (L.) Á. Löve	++	++
Pale persicaria — *Polygonum lapathifolium agg.* L.	+	++
Common knotgrass — *Polygonum aviculare s.str.* L.	+	+
Field chamomile — *Anthemis arvensis* L.	+	+
Wild radish — *Raphanus raphanistrum* L.	-	+
Self-sown rape	++	+
Brome — *Bromus* L. sp.	+/++	+
Shepherd's purse — *Capsella bursa-pastoris* (L.) Medik.	++	+
Field pennycress — *Thlaspi arvense* L.	+	++
Slender meadow foxtail — *Alopecurus myosuroides* Huds.	+/++	+

(+++) harmfulness very high, (++) harmfulness with numerous occurrences, (+) low or locally significant harmfulness, (−) no or marginal occurrence.

7.1.2. Agrotechnical methods of weed management

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

The uncontrolled development of weeds usually results in the occurrence of undesirable vegetation in a quantity or mass significantly limiting the yield.

In integrated production (IP), various methods of weed control should be implemented, taking into account preventive measures and direct methods of weed destruction (Dobrzański and Adamczewski 2013; Melander et al. 2005). The main cause of weeds is the '**soil seed bank'**; therefore, efforts should be made to reduce its quantity as part of various types of treatments, in all possible stages. The strategy to reduce the size of the 'soil seed bank' of weeds should be initiated already in the post-harvest tillage operations. These treatments should in particular target species of perennial weeds reproduced by underground stolons or rhizomes, such as: thistles, field bindweed, sorrel. Subsequent cultivation treatments that stimulate the germination of weed diaspores, followed by the control of their seedlings, significantly reduce the number of active seeds in the top layer of the soil.

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

In integrated production (IP), treatments should be used to limit both **potential weed infestation** and **current weed infestation**. The most important activities include:

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

7.1.3. Non-chemical methods of weed control

Prevention and agrotechnical methods

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

Mechanical methods of weed control

Mechanical care of triticale sowing based on harrowing or inter-row weeding can be performed when justified, and the prevailing conditions allow these treatments. Mechanical care, performed at the right time, is a beneficial treatment. In addition to destroying weeds and soil crust, it improves air-water relations (Spaeth et al.). 2022; Peteinatos et al. 2018; Rasmussen et al. 2009).

7.1.4. Chemical methods of weed infestation control

The precondition for the effective action of herbicides is the correct selection of the appropriate agent and the timely execution of the treatment. In integrated production (IP), it is only allowed to use chemical herbicides listed in the: '**List of herbicides recommended for the integrated production of agricultural plants**'. The list of plant protection products authorised for certified Integrated Production (IP) is available on the Pest Warning Platform at: (https://www.agrofagi.com.pl/133,wykaz-srodkow-ochrony-roslin-do-integrowanej-produkcji-w-uprawach-rolniczych)

Plant protection products listed in the **'List of Herbicides Recommended for Integrated Production (IP) of Agricultural Plants**' and in the **'List of Growth Regulators Recommended for Integrated Production of Agricultural Plants'** are selected from the **'Register of Plant Protection Products**' (https://www.gov.pl/web/rolnictwo/rejestr-srodkow-ochrony-roslin) based on their harmfulness to humans and warm-blooded animals, in accordance with labels, permits, and decisions of the Ministry of Agriculture and Rural Development and the European Commission.

Information on the scope of use of chemical plant protection products in specific crops shall be included in the labels of those products. An auxiliary tool in their selection is a search engine for plant protection products. Current information on plant protection products use is available on the Ministry of Agriculture and Rural Development website at: https://www.gov.pl/web/rolnictwo/ochrona-roslin.

Crop rotation after herbicide use

Herbicides vary in duration of action and biodegradation in soil, which should be taken into account when planning follow-on crops. In each herbicide label, there is the section: 'CROP ROTATION', which provides information on the possibilities for cultivating follow-on crops. Most herbicides do not pose a risk to follow-on crops, but some herbicides persist longer in the soil and may cause symptoms of phytotoxicity or stunting on follow-on crops.

Weed resistance to herbicides and methods of limiting it

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

A factor contributing to the development of weed resistance to herbicides is, inter alia, improper weed control based on a widespread use of herbicides, without taking into account other methods, in particular agrotechnical ones.

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

7.2. PATHOGEN CONTROL

7.2.3. The most important diseases

Triticale, especially its winter form, is susceptible to diseases caused by pathogenic fungi and other pathogenic organisms. Diseases on the plant can be caused by one or several pathogens at the same time. The level of losses in seed yield in triticale cultivation due to the occurrence of diseases is estimated at an average of 5-10 %, although sometimes locally they may be higher. The most common diseases in triticale cultivation are powdery mildew of cereals and grasses, brown leaf spot, septoria nodorum blotch, brown rust, yellow rust, fusarium stem base rot and root rot of cereals, cereal stem breakage, ergot of cereals and grasses, and cereal rhynchosporiosis. In addition to these diseases, other diseases occurring on cereals may occur incidentally in the cultivation of triticale. Fusarium ear blight and sooty mould black mould on wheat ears may occur on the ears. It may be dangerous for consumers to have fusarium ear blight whose perpetrators (mushrooms of the *Fusarium* genus) can produce harmful metabolites. **In integrated triticale production, it is mandatory to systematically monitor the field during the tillering/stem elongation stage, flag leaf stage, and heading to assess the occurrence of diseases (powdery mildew of cereals and grass, septoria nodorum blotch - symptoms on the leaves, brown rust, brown leaf spot, yellow rust) and after heading with particular emphasis on fusarium ear blight.**

The current threat of pathogenic organisms is shown in Table 15. The risk of loss of triticale yield and its quality is posed by several diseases. Their significance varies and they are difficult to recognize, especially when two or more disease entities occur simultaneously on the plantation. They are present on the triticale plantation from the germination stage to the maturity stage of the grain.

Table 15. Economic importance of triticale diseases in Poland

Diseases	Winter triticale	Spring triticale
Brown leaf spot (*Pyrenophora tritici–repentis*)	++	+
Sooty mould black mould on wheat ears (*Cladosporium* spp., *Alternaria* spp., *Epicoccum* spp., *Ascochyta* spp.)	+	+
Fusarium ear blight *Fusarium* spp.	++	+
Fusarium stem base rot and root rot of cereals *Fusarium* spp.	+++	–
Cereal stem breakage *Oculimacula* spp.	++	–
Powdery mildew of cereals and grass (*Blumeria graminis*)	++	++
Soil-borne rhizoctonia infection (*Rhizoctonia cerealis*)	++	–
Brown rust (*Puccinia recondita*)	++	++
Yellow rust (*Puccinia striiformis*)	++	++
Cereal rhynchosporiosis	++	+

(*Rhynchosporium secalis*)		
Septoria nodorum blotch (*Phaeosphaeria nodorum*)	++	+
Ergot of cereals and grasses (*Claviceps purpurea*)	++	++
Sem base rot (*Gaeumannomyces graminis*)	++	–
Seedling blight (complex of pathogens)	++	–
Barley yellow dwarf (BYDV-PAV, CYDV-RPV)	+	–

7.2.2. Methods of monitoring pathogens in triticale cultivation

Weather conditions, especially humidity conditions and the amount and distribution of rainfall during the growing season, temperature and sunshine play a significant role in the severity and timing of disease outbreaks. In integrated production, it is advisable to know the sources of infection and the conditions that are conducive to the occurrence of diseases. Thanks to this, it is possible to determine with high accuracy which disease is problematic and assess its severity in order to apply a possible harmfulness threshold. It also reduces the prevalence of certain diseases in subsequent years through actions, such as agrotechnical measures and sowing varieties resistant to pathogen infestation. Table 16 provides indicative conditions under which the main fungi causing triticale diseases may develop (Korbas et al. 2015, 2016; Kryczyński and Weber 2011).

Table 16. Indicative conditions conducive to the development of selected triticale pathogens

Disease	Sources of infection	Favourable conditions for development	
		temperature [°C]	soil and air humidity
Brown leaf spot (*Pyrenophora tritici–repentis*)	infested grain, post-harvesting residue	18–28	moistening the leaves to cause infection
Sooty mould black mould on wheat ears (*Cladosporium* spp., *Alternaria* spp., *Epicoccum* spp., *Ascochyta* spp.)	post-harvesting residues, conidial spores carried by rain and wind	15–25	high relative air humidity
Fusarium ear blight *Fusarium* spp.	post-harvesting residues, spores spread with rain drops	15–25	heat, high relative air humidity
Fusarium stem base rot and root rot of cereals *Fusarium* spp.	post-harvesting residues, infested caryopses, spores spread with raindrops	5–25	high relative air and soil humidity or desiccated soil
Cereal stem breakage *Oculimacula* spp.	post-harvesting residues, conidial spores, ascospores	5–15	high air and soil humidity
Powdery mildew of cereals and grass (*Blumeria graminis*)	conidial spores, ascospores	5–30	relative air humidity 50-100 %
Soil-borne rhizoctonia	sclerotia in the soil, post-	15–25	heat, dry, no moisture

infection (*Ceratobasidium cereale*)	harvesting residues		in the soil
Brown rust (*Puccinia recondita*)	self-sown seeds, spores in the air	15–20	periodic daily increase in air humidity
Yellow rust (*Puccinia striiformis*)	urediniosporous of volunteer and winter cereals	10–15, new pathotypes 10-28	high humidity, new pathotypes in dry and hot conditions
Cereal rhynchosporiosis (*Rhynchosporium secalis*)	infested grains, conidial spores	5–12	high humidity
Septoria nodorum blotch (*Phaeosphaeria nodorum*)	self-sown seeds, spores in the air	10–20	high air and soil humidity
Ergot of cereals and grasses (*Claviceps purpurea*)	sclerotia in soil or seed,	18–25	dry and warm
Seedling blight (complex of pathogens)	soil, seeds	moderate	high
Barley yellow dwarf (BYDV-PAV, CYDV-RPV)	infected volunteer seeds, presence of aphids	10–25	moderate relative humidity

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

In addition to knowing the conditions conducive to the occurrence of a given disease, it is also important to define it correctly. Table 17 presents information that will facilitate the diagnosis of triticale diseases present during the growing season. Thanks to this, it is possible to determine with high accuracy which disease is involved and assess its severity. These messages should be used to precisely determine the timing of control when a chemical method is needed to apply the existing threshold of harmfulness for a given disease.

Pathogenic fungi can appear on all parts of rye and occur from the germination stage when the embryonic root emerges from the caryopsis (BBCH 05) to the end of the maturation stage (BBCH 89). Depending on the disease, symptoms occur on different parts (organs) of triticale (table 18).

Table 17. Diagnostic features of major triticale diseases

Disease (pathogen)	Diagnostic properties
Brown leaf spot	In the spring, small oval stains of yellow appear on the lower leaves with a brown spot in the centre. These stains are surrounded by a distinct chlorotic rim. The disease may also manifest itself in the form of brown spots surrounded by a chlorotic rim. Symptoms increase at a time when numerous rainfalls and high humidity are recorded during the growing season. On older leaves, the described spots combine with each other, and the leaves turn yellow and brown. Infected leaves dry up.
Sooty mould black mould on wheat ears	A characteristic black coating reminiscent of soot that covers the ear partially or completely, occurs on the mature ears before the harvest. Ears infested by fungal pathogens change the colour of ears to grey-brown (blackened ears).
Fusarium ear blight	Lesions are observed on ears and grains. Yellow, partially or completely discoloration of spikelets, initially single, then more, indicates infection by the pathogens. In conditions of high humidity, the infected ears are covered with fluffy white or pink

	bloom of the mycelium. Clusters of orange spores can appear on the spikelets. Grain infested by fungi of the genus *Fusarium* is distorted, wrinkled and often has a pink colour; it can also contain strongly poisonous metabolites (mycotoxins).
Fusarium stem base rot and root rot of cereals	The roots and the base of the blade undergo the fungal infection. The first symptoms of the disease are already visible in autumn. Leaf sheaths change from green to brown. Initially, there may be brown or brown streaks, lines and irregularly shaped spots. Sometimes the browning of the whole base of the stem and roots can be observed. The final stage of the Fusarium stem base and root rot is complete, premature death of infected shoots and so-called bleaching of ears.
Cereal stem breakage	Symptoms can be observed in autumn or early spring. Initially, they are difficult to recognise. These are small, slightly elongated, brown stains occurring on the surface of the leaf sheaths. In the central part of the spots caused by *Oculimacula* spp., black patches are formed. In case of severe infestation, the entire base of the barley stalk decays. In the infested area, the stem is brittle and breaks easily. Heavily infested stems have white, barren ears and break off easily when they are pulled out of the ground. The pathogens do not infest the roots.
Powdery mildew of cereals and grass	The first symptoms of the disease on winter cereals can be observed in autumn. On the leaves, the leaf sheaths, and later on the green stems there are clusters of a white bloom composed of mycelium, stems and conidial spores (oidia) of the pathogen. On the older, compacted bloom, dark brown closed, globose ascocarps appear, that look like black spots (cleistothecium). Strongly infested leaves and leaf sheaths turn yellow and prematurely die. On the ears, there is a white, floury coating on the surface of the chaff or only on their edges, consisting of a loose layer of mycelium, stalks, and conidial spores. On the older, compacted bloom, dark brown closed, globose ascocarps appear, that look like black spots (cleistothecium).
Soil-borne rhizoctonia infection	Initially, dark rimmed spots with very clear borders appear on the leaf sheaths. These spots are superficial and have a pointed finish. The centre of the spot is bright, often with a bloom of beige mycelium and small brown spore fungus — sclerotia. Clear, sharp pointed spots appear on the stem base. The roots can also be affected by fungus.
Brown rust	Symptoms of infestation can be observed in all stages of plant development. Uredinia, i.e. urediniospore clusters (propagating spores) develop mainly on the leaves under the skin, the appearance of chlorotic spots often precedes the occurrence of uredinia which are initially slightly raised, puffy, oval, or almost round, light-brown colour. At the end of vegetation season, black teliospor clusters (autumn spores) are visible. The leaves that were early and heavily infested by brown rust can dry partially or completely.
Yellow rust	Symptoms of the disease on the leaves are very characteristic. Uredinia are formed under the skin and are arranged linearly, between the nerves. They have a yellow colour, an elongated shape and are slightly raised. Rows of uredinia form yellow stripes several millimetres long. Symptoms of the disease are most pronounced in May and June. On the ears, one can see the bleaching of individual chaff, and yellow, orange, and brown nodules on the chaff and awns. Clusters of orange spores on the inside of the chaff with bleaching symptoms.
Cereal rhynchosporiosis	Symptoms of the disease on winter triticale can occur as early as autumn. On the leaves, there are oval or lenticular spots of steel-green, greyish-white, or straw colour, with a brown border separating the infested part from the healthy part. Sometimes there is a chlorotic border around the spots. Early and severely infested leaves can dry

	out.
Septoria nodorum blotch	The spots on the leaves are initially yellow-green, then brownish, and they take a similar shape to the lenticular. Young spots often have a chlorotic rim. Older spots are mostly light brown, blend together and may also include leaf sheaths. Severe leaf damage can be observed in June and July. Poorly visible pycnidia (scattered irregularly on the stain) can appear on the surface of the stains; during wet weather, a pink mucus containing conidial spores is discharged from these stains. Early and heavily infested leaves may die. Early and heavily infested leaves may die off. On the ears, purple-brown spots are visible on the chaff of green ears, often forming from the top of the chaff downwards. In the dead leaf and chaff tissue during wet weather, dark brown pycnidia form, which then release a pink, mucoid secretion containing conidial spores.
Ergot of cereals and grasses	During flowering, drops of yellowish honey dew appear on the ears. Shortly thereafter, ergot sclerosis develops in individual spheres instead of grains. These are elongated bent purple-red cones, hard and brittle at the same time. Ergot sclerosis contain metabolites with toxic properties.
Seedling blight	Infested sprouts are twisted snakelike and often die before reaching the surface of the soil (pre-emergence blight). Sick seedlings that have grown above the surface of the earth are weakened, with brown spots, often covered by a white-pink coating (post-emergence damping-off).
Barley yellow dwarf	Triticale leaves may turn red or yellow. Infested plants excessively tiller, are inhibited in growth, and have strongly reduced ear-bearing stems. The ears are not fully filled or barren. The grain is less plump and of inferior quality.

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

Table 18. Occurrence of symptoms of diseases on individual organs of triticale

Disease	Root	Blade	Leaf	Leaf sheath	Ear	Grain
Brown leaf spot	–	–	+	+	+	+
Sooty mould black mould on wheat ears	–	–	–	–	+	+
Fusarium ear blight	–	–	–	–	+	+
Fusarium stem base rot and root rot of cereals	+	+	–	+	–	–
Cereal stem breakage	–	+	–	+	–	–
Powdery mildew of cereals and grass	–	+	+	+	+	–
Soil-borne rhizoctonia infection	+	+	–	+	–	–
Brown rust	–	+	+	+	+	–
Yellow rust	–	–	+	+	+	+
Stem rust of cereals and grasses	–	+	–	+	–	–
Cereal rhynchosporiosis	–	–	+	+	–	–
Septoria nodorum	+	+	+	+	+	+

blotch						
Ergot of cereals and grasses	–	–	–	–	+	+
Seedling blight	+	–	+	+	–	–
Barley yellow dwarf	–	+	+	+	–	–

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

7.2.3. Agrotechnical methods of reducing pathogens

The agrotechnical method is based on the correct and timely execution of all actions related to planning and operation of sunflower cultivation.

Agrotechnical activities play a significant role in combating or preventing diseases. Among other things, the following elements of agrotechnics are important:

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

In order to reduce the incidence of crop rotation diseases, a break in cultivation should be maintained. When the break in triticale cultivation is too short, one can expect an increased incidence of diseases, especially caused by fungi of the genus *Fusarium*. The right harvest date also influences the presence of fungi in the crop, on the straw or stubble. The measures mentioned above (Table 19) that are implemented in the agrotechnical method make it possible to greatly reduce the risk of diseases caused by fungi. It is advisable to use as many elements as possible that reduce the occurrence of diseases. Triticale which grows and develops in optimal conditions will enable obtaining a satisfactory yield, both in terms of quality and quantity.

Table 19. The most important methods of controlling triticale pathogens

Disease	Agrotechnical method
Brown leaf spot	appropriate crop rotation, careful incorporation of stubble, destruction of volunteer plants, sustainable fertilisation
Sooty mould black mould on wheat ears	appropriate crop rotation, spatial isolation of winter and spring varieties, harvesting at the optimal time
Fusarium ear blight	appropriate crop rotation, careful incorporation of post-harvesting residues, destruction of volunteer seeds and optimisation of nitrogen fertilisation
Fusarium leaf blight	appropriate crop rotation, careful incorporation of stubble, destruction of volunteer plants, sustainable fertilisation
Fusarium stem base rot and root rot of cereals	appropriate crop rotation, careful incorporation of stubble, destruction of volunteer plants
Cereal stem breakage	appropriate crop rotation, careful incorporation of stubble, destruction of volunteer

	plants, optimization of nitrogen fertilisation
Powdery mildew of cereals and grass	careful incorporation of stubble, destruction of volunteer plants, sowing at the optimal agrotechnical time, appropriate sowing density, balanced fertilisation (excess nutrients must be prevented, especially nitrogen), spatial isolation of winter varieties from spring varieties
Soil-borne rhizoctonia infection	appropriate crop rotation
Brown rust	careful incorporation of stubble, destruction of volunteer plants, sowing at the optimal agrotechnical time, appropriate sowing density, balanced fertilisation, prevention of excess nutrients (especially nitrogen), spatial isolation of winter varieties from spring varieties
Yellow rust	careful incorporation of stubble, destruction of volunteer plants, appropriate sowing density, balanced fertilisation, spatial insulation of winter varieties from spring varieties
Cereal rhynchosporiosis	appropriate crop rotation, careful incorporation of stubble, destruction of volunteer plants, sustainable fertilisation
Septoria nodorum blotch	appropriate crop rotation, careful incorporation of stubble, destruction of volunteer plants, sowing at the optimal agrotechnical time, spatial isolation of winter and spring varieties, use of healthy seed, sowing of early ripening varieties, appropriate sowing density, sustainable fertilisation (abundance of nutrients should be prevented, especially nitrogen)
Ergot of cereals and grasses	Thorough cleaning of grains, preferably on gravity tables, cultivation of varieties with greater resistance (varieties with a short spike opening period during flowering), mowing grass before sclerot formation and incorporation of post-harvesting residues to cover the sclerot
Seedling blight	appropriate crop rotation, careful incorporation of stubble, destruction of volunteer plants, sowing at the optimal agrotechnical time, appropriate sowing density, sustainable fertilisation
Barley yellow dwarf	rational fertilisation, destruction of volunteer plants, sowing cereals at the optimal time

7.2.4. Chemical methods of reducing pathogens

The use of a chemical method in triticale cultivation is currently possible by applying grain treatment and spraying plants during the growing season. **For sowing in the integrated production of winter and spring triticale, the use of certified and treated seed in accordance with the ESTA standard or an equivalent standard is required.**

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

The list of plant protection products authorised in Poland is published in the relevant register. Information on the scope of application of pesticides in individual crops is included on the labels. The plant protection product search engine is a helpful tool when selecting pesticides. Current information on plant protection products use is available on the Ministry of Agriculture and Rural Development website at: https://www.gov.pl/web/rolnictwo/ochrona-roslin..

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

Sowing of treated grain is the only effective way to combat the following pathogens: seedling blight, stinking smut, loose smut, and snow mould. Seed dressing protects the germinating kernels from infection by fungi and pathogenic organisms that may be on the surface and inside the kernel as well as living in the soil.

The use of fungicide treatments during the growing season depends on the severity of the disease. In years with less pressure from pathogenic fungi, dressed seed should be planted and one/two spraying procedures with appropriate fungicide should be performed, without neglecting the treatment within the T-1 period. However, in years when weather conditions favour the occurrence of diseases, it is advisable to perform three treatments. There may be exceptional situations where conditions favour an epidemic of a given disease, especially during prolonged high temperatures in the autumn, then additional treatment should be considered taking into account the active substances previously used for protection. In general, the first treatment in winter triticale, less often in spring triticale, can be performed from the end of the tillering stage (BBCH 29) to the stem elongation stage - the first and second nodes (BBCH 30-32). Obviously, if symptoms occur earlier in high intensity, the treatment should then be advanced and performed at the beginning of the tillering stage which, however, is rare in practice. This kind of treatment carried out at the end of the tillering/early stem elongation stage reduces the incidence of diseases on leaves and stem base diseases. Performing this treatment allows for the control of diseases occurring on the leaves, such as powdery mildew of cereals and grass, brown rust, and septoria nodorum blotch - symptoms on the leaves.

This treatment, when there is no risk of stem breakage and fusarium head blight and root rot, can be delayed until the disease has occurred at such an intensity that the economic harmfulness threshold is surpassed. The treatment for the flag leaf is performed primarily in the stage from the beginning of the sheath thickening of the flag leaf (BBCH 41) to the visible stage of the first awns (BBCH 49). There are situations where this treatment is performed in the stage of BBCH 37-39 — in the final stage of stem elongation. The treatment performed on time is intended to protect mainly the flag leaf, sub-flag leaf and sub-sub-flag leaf. Keeping the middle part of the field green for a long period, i.e. at least two upper leaves, to a large extent guarantees obtaining a high grain yield from such a wheat plantation. The assimilation capacity of the highest leaves is largely dependent on the protection of the ear in nutrients and water. In the cultivation of triticale, performing the treatment in time T-2 allows to combat the following: powdery mildew of cereals and grass, septoria nodorum blotch - symptoms on the leaves, yellow rust, and brown leaf spot.

Another important treatment performed during the heading stage is aimed mainly at combating the pathogens of fusarium ear blight and yellow rust. Losses caused by the pathogens of fusarium ear blight or yellow rust include reductions in quantity, grain weight, and quality deterioration, and in the absence of protection against *Fusarium* spp., there is a total loss of yield due to excessive mycotoxin content. BBCH 51-55 – beginning of heading is a recommended stage for treatment aimed at controlling ear diseases, while BBCH 59 — the end of heading usually closes the date of use, but there are derogations, e.g. in wheat. This information is included in the labels of fungicides.

Harmfulness thresholds

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

For leaf diseases in the early developmental stages (BBCH 21-29 scale), 100 to 150 plants (depending on field size) taken from several randomly selected sites should be analysed to identify the first signs of disease based on a blade, the leaf sheath of the test plants, or on the leaves taken from the monitored plants, or on the leaves of the observed plants growing on the plantation.

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

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

For fusarium ear blight and other ear diseases, the harmfulness threshold is the first symptoms of the presence of the pathogens or a positive result of an envelope test. It consists in taking a few dozen ears from different parts of the field which are then spread out on pre-moistened newspaper, then which is folded and placed in a paper bag. All of this is then placed in a plastic bag and then left in a dark place, such as a drawer. If there is more than one field, it is best to describe each bag, indicating where the sample was taken and the date and time. The test is best assessed 96 hours after starting, checking if the paper is still damp after 48-72 hours, and if it is dry it should be moistened to maintain the moisture content which is conducive to fungal growth. During heading, several such tests can be performed, especially when it is warm and humid, and previous tests did not show the presence of fungi causing the disease on the ears.

Decision support systems

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

In integrated production, treatment decisions should be based on available damage thresholds (Table 20).

When several disease pathogens are present at the same time, but not exceeding the harmfulness threshold, it makes sense to add these specific threshold values. When the sum of the presence of pathogens reaches the threshold values for one of the pathogens then a decision can be made to tackle it with a fungicide. As per a well-known principle, it is better to do something sooner than later.

Table 20. Indicative thresholds for the economic harmfulness of triticale diseases

Disease	Observation date	Economic harmfulness threshold
Brown leaf spot	during the tillering stage	10-15 % of infested plants with first symptoms of infestation
	during the stem elongation stage	5 % of leaves with first symptoms of infestation
	in heading stage	5 % of leaves with first symptoms of infestation
Cereal stem breakage	from the beginning of the stem elongation stage to the stage of the first node	20-30 % of stems with infestation symptoms
Powdery mildew of cereals and grass	during the tillering stage	50-70 % of plants with first symptoms of infestation (isolated white clusters of fungal structures)
	during the stem elongation stage	10 % of plants with first symptoms of infestation
	in heading stage	first symptoms of infestation on sub-flag or flag leaf or on ear
Brown rust	during the tillering stage	10-15 % of leaves with initial infestation symptoms
	during the stem elongation stage	10 % of stems with infestation symptoms
	in heading stage	first symptoms of infestation on sub-flag or flag leaf
Yellow rust	during the tillering stage	30 % of plants with first symptoms of infestation
	during the stem elongation stage	10 % of sub-flag leaf surface infested
	in heading stage	first symptoms of infestation on sub-flag or flag leaf
Cereal rhynchosporiosis	during the tillering stage	15-20 % of leaf area with disease symptoms
	during the stem elongation stage	15-20 % of leaf area with disease symptoms
Septoria nodorum blotch	during the tillering stage	20 % of plants with first symptoms of infestation
	during the stem elongation stage	20 % of sub-flag leaf surface infested or 1 % of leaves with fruiting bodies

	at the beginning of heading	10 % of sub-flag leaf surface infested or 1 % of leaves with fruiting bodies
	at full heading stage	1 % of flag leaf surface infested

7.3. REDUCING LOSSES CAUSED BY PESTS

7.3.1. The most important pests

In Poland, the most important pests that occur on cereal plantations are aphids, cereal leaf beetles and gall midges. We've been able to observe for some years, locally and sometimes in huge numbers, the occurrences of some other pests, such as Bishop's Mitre, tortoise bug, ground beetle, cereal chafer, leaf miner, oscinella frit, delia platura, and soil pests, mainly turnip moths, grubs and wireworms. Cereals can also be damaged by snails and slugs, rodents, thrips, cephus pygmeus, chlorops ringens, nematodes, birds and game, and caterpillars of leafroller moths (Table 21) (Mrówczyński et al. 2017; Tratwal et al. 2017; Hołubowicz-Kliza et al. 2018; Grzebisz et al. 2021). Pests can cause damage to both aerial and underground parts of plants (tables 22 and 23).

Systematic monitoring of the field from emergence to the beginning of maturity, at least once a week, for the occurrence of pests (aphids, cereal leaf beetles, and gall midges) (direct inspection of the plants, yellow pots, etc.) is an extremely important element of integrated production of triticale.

Table 21. Current and projected importance of triticale pests in Poland

Pest	Current	Forecast
Wireworms	+(+)	+++
Bishop's Mitre	++	+++
Bibionidae (march flies)	+	++
Ground beetle	++(+)	+++
Leaf miners	+(+)	++
Aphids	++(+)	+++
Cereal chafer	+	++
Chlorops ringens	+	++
Grubs	++	+++
Frit fly	++	+++
Gall midges	++	+++
Cutworms	++	+++
Leafhopper	+(+)	++
Cereal leaf beetle	++(+)	+++
Maggots	+(+)	++
Thrips	+(+)	++
Leafroller moths	+	++
Cephus pygmeus	+	++

Tortoise bug	++	+++
Rodents	(+)	+
Snails and slugs	+	++
Game and birds	+	+(+)

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

Table 22. Damage to underground parts of triticale plants caused by pests

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

Table 23. Damage to the aerial parts of triticale plants caused by pests

Pest	Damage description
Bishop's Mitre	Foraging on leaves and stems — yellowing and drying of leaves. Foraging on kernels — bleaching of ears, reduction of kernels in the ear, underdevelopment of kernels, and deterioration of kernel quality.
Leaf miners	Eating out the parenchyma between the upper and lower leaf skin, usually along the veins — reducing the assimilative surface (usually flag and sub-flag leaves).
Aphids	Direct damage (sap sucking) — loss of turgor, twisting and wilting of leaves. Indirect damage (transmission of viruses, mainly BYDV) — leaf discolouration, tillering, dwarfism, absence or low number of spikelets. In addition, secondary infestations by the disease pathogens.
Cereal chafer	Damage to flowers and forming grains leading to the bleaching of parts of the ear (imago), and damage to the root system (larvae).
Chlorops ringens	Damage to young seedlings and growth cones leads to stunted growth, shoot distortion, excessive tillering, yellowing of leaves, shortened ears or dying of entire plants.
Frit fly	Damage to the base of the shoot can result in whole plants dying or excessive tillering with few (or no) spikelets (characteristic yellowing heart leaf).
Gall midges	Weakening and shortening of the stem, abnormal development of ears and

	grains, reduced quality and germination of grains.
Leafhoppers	Due to sap sucking — weakening of growth, wilting and drying of plant parts. Like aphids, leafhoppers can be vectors of viruses (e.g. WDV).
Cereal leaf beetle	Eating the tissue along the leaf veins — reduction in assimilative surface area and photosynthesis, secondary infestation by disease pathogens.
Snails and slugs	After emergence, the seedlings are either entirely eaten or nibbled until completely cut off by slugs just above the soil surface.
Thrips	Leaf deformation, failure of ears to emerge from the leaf sheaths, bleaching of the tops of the ears, deformation of the grains and deterioration in grain quality.
Game and birds	Eating of seeds or germinating plants during their emergence (birds) and gnawing of plants at later stages of development (game).
Leafroller moths	The greatest losses occur when caterpillars fodder on the ears; they usually destroy 3-4 kernels.
Cephus pygmeus	Larvae foraging causes underdevelopment of the ears or inadequate grain filling. Plants damaged at the base of the stem are easily broken.
Tortoise bug	Foraging on leaves and stems — yellowing and drying of leaves. Foraging on kernels — bleaching of ears, reduction of kernels in the ear, underdevelopment of kernels, and deterioration of kernel quality.

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

7.3.2. Pest monitoring methods

Monitoring for the presence of pests in a plantation is a very important part of integrated plant protection. Continuous observation facilitates the assessment of the current situation in the field and, if necessary, allows for a quick response. Therefore, it is necessary to systematically monitor the occurrence of pests from the time of emergence to maturation, at least once a week, using appropriate methods. The basic element underpinning a properly set date for pest control is the monitoring of pest flights and number. Monitoring is carried out primarily on the basis of visual inspection or – in the case of soil pests – soil sieving. Other methods are also useful, such as sweep-netting or sticky boards. The basic method of plantation inspection is visual inspection (tour). Depending on the shape of the field, it should include the edge of the plantation and two diagonals. Depending on the pest species, the average number of pests per 1 m^2 or 100 randomly selected plants should be checked. Such observations should be carried out in several places on the plantation. A useful method is sweep-netting. This is an easy and quick way to make an initial assessment of the species composition and number of insects on a plantation. Correctly applied, this method of monitoring makes it possible in a relatively short time to obtain preliminary information not only about pests, but also about other insects, including beneficial ones located on the plantation. However, it should be remembered that this method is not precise and in the event of a detected threat, more detailed inspection of the plantation should be carried out. For the purpose of initial inspection, 25 strokes should be made with a sweep net from the edge of the plantation, moving inside it. Sweep-netting should always be carried out in the place most vulnerable to pest infestation, for example from last year's location of the crop concerned. Observations on the occurrence of soil pests involve sifting soil from several locations from dug holes measuring 25 × 25 cm and a depth of 30 cm. The essence of proper pest risk assessment is understanding the basics of the morphology and biology of a given pest species, such as the timing of potential occurrence on the crop. Monitoring should be carried out both in order to determine the time of infestation and number of harmful insects on the plantation, as well as after the procedure to check the effectiveness of the control. In case of unsatisfactory effectiveness, the occurrence of resistance or prolonged infestations of harmful insects, such treatment gives the possibility of a quick reaction and, if possible, a repeat treatment. Due to many factors determining the occurrence of pests, monitoring should be carried out on each plantation. Proper inspection requires knowledge of pest morphology biology. Regardless of the monitoring method used, the results of observations should be recorded (Tratwal et al.). 2017).

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

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

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

The Online Pest Warning System operated by the Institute of Plant Protection – National Research Institute and partner institutions features, among others, the results of monitoring of individual stages of pest growth in selected locations for the needs of short-term forecasting. If the threshold of economic harmfulness is exceeded in individual cases, the system indicates the need to perform treatments. In addition, the system offers instructions that facilitate proper control of plantations and making decisions about the optimal treatment dates. For each pest species, basic information is provided on its morphology, biology and methods of field observation, as well as the value of the thresholds for economic harmfulness. Economic harmfulness thresholds are the fundamental basis for rational protection. The principles and deadlines for their observation and the harmfulness thresholds are set out in Table 24.

Table 24. Observation deadlines and economic harmfulness thresholds to triticale pests

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

7.3.3. Agrotechnical methods for pest control

One of the basic principles of integrated plant protection for triticale is preventive measures, based primarily on agrotechnique (Table 25). Appropriate use of agricultural technology and the replenishment of any mineral nutrients shall improve the condition of plants in the early growth stages, when they are particularly vulnerable to attack from particular agrophage species. In addition, faster growth shall help to smother weeds which often provide a food base for some pests. Proper pre-sowing and post-sowing cultivation reduce the threat from pests, especially soil pests and those who overwinter in the soil. It is very important to implement crop rotation correctly. Many pests overwinter in the top layer of soil or leftover plant residues. In the case of monocultures, pests after wintering have facilitated access to the food base. For this reason, spatial isolation is recommended, including from host plants of multivorous pests. Spatial isolation also helps make certain pests fly over longer distances. Appropriate measures to reduce the potential damage caused by individual pest species can also be taken at the seed sowing stage. The faster the initial vegetation stage of the plants, the more possibilities there are to anticipate the period of the greatest threat from the pests that are particularly dangerous to the emerging crops. The plant density is also important. Sowing too densely makes it easier for pests to spread, while sowing too sparsely favours weeds on which, for example, aphids thrive. The timing of the harvest is also very important — harvesting too late creates the risk of greater losses, especially in terms of yield quality. After the harvest, it is important to carry out a set of post-harvest cultivations aimed at thoroughly disintegrating plant residues (overwintering sites for certain pests), and reducing weed seeds, including perennial weeds. In turn, the soil layer covers the wintering stages of pests, weed seeds, and fungal spores. It also brings to the surface pests that are found deeper, exposing them to adverse weather conditions. Soil pests are also mechanically destroyed at the same time (Mrówczyński et al. 2017; Tratwal et al. 2017).

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

Table 25. Agrotechnical methods and ways to protect triticale against pests

Pest	Methods and measures of protection
Wireworms	proper crop rotation, ploughing, discing, deep autumn ploughing, early sowing and increased sowing rate, weed control, spatial isolation from other cereals, root crops and brassicas
Bibionidae (march flies)	spatial isolation from other cereal plants, early seed sowing, increasing the standard of seed sowing
Bishop's Mitre	cultivation measures, spatial isolation from meadows and pastures, weed control
Ground beetle	spatial isolation from other cereal plants, increasing the standard of seed sowing, early seed sowing
Leaf miners	spatial isolation from other cereals, meadows and wasteland
Aphids	spatial isolation from other cereal plants, early seed sowing, balanced fertilisation, spraying of plants with selective insecticides, especially the edges of plantations
Cereal chafer	tillage operations, mainly deep pre-winter ploughing, spatial isolation from meadows and pastures
Nematodes	tillage operations, correct crop rotation, 5-year break in cultivation, spatial

	isolation from other cereal crops
Chlorops ringens	spatial isolation from other cereal crops, late sowing of winter cereals, increasing the standard of seed sowing
Grubs	ploughing, discing, harrowing, weed control, increasing the sowing rate of seeds
Frit fly	spatial isolation from meadows, pastures, grass seed plantations, control of weeds and cereal volunteers, delayed sowing of winter crops, accelerated sowing of spring crops
Gall midges	tillering operations, spatial isolation from other cereal crops, balanced fertilisation
Cutworms	spatial isolation from other cereals and crucifers and brassica vegetables, early sowing of grain, weed control, increasing the sowing rate of grain, increasing the fertilisation rate
Leafhopper	tillering operations, spatial isolation from other cereal crops, sowing of early varieties, increasing the fertilisation rate
Cereal leaf beetle	tillering operations, spatial isolation from other cereal plants, balanced fertilisation, spraying of plants, especially at the edge of the field
Snails and slugs	ploughing, discing, careful tillage, liming, destruction of weeds, spatial isolation from other cereals and crucifers and brassicas, early and deeper seed sowing, increasing the seed sowing rate
Maggots	spatial isolation from other cereal plants, early seed sowing, increasing the standard of seed sowing
Thrips	tillage, spatial isolation from other cereal plants, balanced fertilisation, plant spraying
Leafroller moths	tillering operations, spatial isolation from other cereal plants, increasing nitrogen fertilisation
Tortoise bug	cultivation measures, spatial isolation from meadows and pastures, weed control

7.3.4. Chemical methods of pest control

Plant protection products should be used in accordance with the current list of plant protection products recommended for triticale in integrated production (IP). Messages provided on the Online Pest Warning System (www.agrofagi.com.pl) can be helpful. Use instructions on the label should be read before application. The list of plant protection products authorised in Poland is published in the relevant register. Information on the scope of application of pesticides in individual crops is included on the labels. The plant protection product search engine is a helpful tool when selecting pesticides. Current information on plant protection products use is available on the Ministry of Agriculture and Rural Development website at: https://www.gov.pl/web/rolnictwo/ochrona-roslin.

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

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

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

In biological pest control, three main methods are distinguished:

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

The use of biopreparations containing parasitic microorganisms is not common in field cultivation. First of all, there is little interest from producers in these products, as their efficacy is often much lower compared to the application of chemical plant protection products. Their efficacy is influenced by weather conditions in the field, which often change. These are: temperature, humidity and insolation. However, it must be remembered that the introduction of these factors into the environment keeps them there for a long time, and under favourable conditions, they can limit the populations of many pests.

No biological plant protection products based on micro-organisms are currently registered in the cultivation of spring and winter triticale. Bioinsecticides and biofungicides are not available, which according to the label are available in crops such as spring and winter oilseed rape, sweet corn, spring and winter wheat, spring rye, beetroot, potato, and many other field crops.

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

In the cultivation of triticale, a large role can be played by conservation biological protection, which consists in the modification of the agricultural landscape by humans in order to create appropriate conditions for the action of beneficial organisms occurring in the environment (Sosnowska 2018, 2022). The number of beneficial organisms can be increased, among others, by sowing melliferous plants in the vicinity of crops, flower strips or leaving natural furrows. Midfield woodlots and bushes play a big role. These sites serve as habitats for those organisms that significantly reduce populations of various pests. Therefore, it is necessary to ensure an increase in the number of beneficial organisms in the vicinity of cultivation through field margins and flower strips. A very important element is the rational use of selective chemical plant protection products, allowing to reduce their negative effects on beneficial organisms. The decision on the need to perform chemical treatment in the field should be made on the basis of the real threat of pests to cultivation.

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

Aphids can be a problem in triticale. In natural conditions, aphid populations are reduced by many species of predatory insects, such as ladybirds (Coccinellidae). One larva, throughout its development (approx. 30 days), can eliminate from 100 to 200 aphids. A beetle eats 30-250 aphids a day. This is a lot, but aphids develop very fast. Given that aphid flights usually occur earlier than those of ladybirds and other useful insects, it is necessary to decide whether chemical treatment with a plant protection product is needed. If necessary, it should be done as early as possible, before the flight of natural enemies, or restricted to the edge strips of the plantation, or even for a spot treatment by choosing a selective insecticide. Net-winged insects (Neuroptera) also eat aphids. Green lacewing larvae eat up to 400 aphids. However, despite enormous aphidicidal effectiveness, the high motor activity of these insects significantly hinders the ability to control their populations, both natural and artificially introduced into crops. Aphids are also preyed upon by species of Cantharidae, Cecidomiidae, Dermaptera, as well as predatory insects such as specialised Aphidiidae

(Tomalak 2008). Among Heteroptera, an important role is played by the predatory species of Miridae, Anthocoridae and Pentatomidae.

Spiders play an underappreciated role in nature. There are running spiders, large web spiders and also small spiders in the fields. The role of spiders is extremely important, as they destroy agrophages during the initial period, even before other natural enemies of pests appear. Often more insects are caught in the spider's web than the predator is able to eat. Unfortunately, spiders are multivorous, so beneficial insects also fall victim to them.

Under favourable conditions (high humidity and temperature above 20°C), entomopathogenic fungi belonging to the family Entomophthoracea play a significant role in the environment. These fungi can cause epizootic diseases, i.e. mass extinction of aphid colonies. The development of insecticide fungi is promoted by water habitats, strongly humidified habitats, forests, woodlots, rushes and meadows. Forests are more than twice as rich in entomopathogenic fungi as agroecosystems (Tkaczuk et al. 2016). Entomopathogenic fungi can reduce populations of wintering pests in soil conditions, such as cutworms and cereal leaf beetles. Insecticidal fungal species active in the soil include: *Beauveria bassiana*, *Metarhizium anisopliae* and *Cordyceps fumosorosea*. The effectiveness of these fungi is optimal at high humidity and a temperature of 25°C. Entomopathogenic fungi also act on the surface of the plant. One can often find parasitised insects on the leaves, such as aphids, maggots, thrips, and others. Entomopathogenic fungi and viruses can also play an important role. Among bacteria, *Bacillus thuringiensis* is of particular importance in the soil environment.

In the environment, not only beneficial insects and microorganisms play a role in reducing populations of harmful pests. There are other animals, such as amphibians, birds, or mammals (Wiech 1997). The beneficial role of leaf toad has been known for a long time. This large amphibian feeds on a variety of foods, predominantly snails and insects, often harmful ones. One of the insectivorous mammals is the mole. It is a useful animal that feeds on grubs and other insects found in the soil. The largest representative of insectivorous mammals is the hedgehog, which hunts at night, and its food consists of insects, snails, and other creatures. Birds play a useful role in the environment. Therefore, in integrated triticale production, the list of obligatory activities and treatments requires the creation of appropriate conditions for the presence of birds of prey, which involves the setting up of resting poles. Birds destroy various pests.

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

Unfortunately, it is not possible to ensure the protection of triticale with the exclusive use of biological agents. The strategy for the protection of this crop should include a set of measures based on various methods, mainly non-chemical, and seeking to minimise the use of chemical plant protection products. Although we do not currently have a large assortment of biological plant protection products for field crops, the current strategies of the European Union, as well as the reduction of chemical plant protection products, will contribute to increasing the spectrum of these products in the coming years.

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

Advantages of biological agents and biological protection:

- environmental safety;
- enriching the biodiversity of the agricultural landscape;
- are safe for the consumer and beneficial organisms;
- do not require a withdrawal period;
- once introduced into the environment, they can persist for a long time and, under natural and optimal conditions for their development, can reduce pest populations without reintroduction;
- no residues;
- non-toxic to entomophages;
- they are often specific to certain groups of organisms (e.g. they only affect aphids), allow to reduce the use of chemical plant protection products, and protect the biodiversity of the environment.

They also have disadvantages, such as: sensitivity to environmental conditions (temperature, humidity), expensive to manufacture and use, short life in the preparation, the need for precision treatments, slow mechanism of action. This may discourage producers from using them, so it will be important to introduce funding for the use of biological agents.

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

Detailed information on registered plant protection products for the protection of triticale can be found at:

- Search engine for all plant protection products (including biological ones) registered in Poland
https://www.gov.pl/web/rolnictwo/wyszukiwarka-srodkow-ochrony-roslin---zastosowanie

- Methodologies of Integrated Agricultural Crops Protection on the IOR-PIB website
https://www.agrofagi.com.pl/94,rosliny-rolnicze

Protection of bees and other pollinators

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

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

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

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

- rational use of chemical plant protection products and making decisions based on the real-time pest risk assessment of triticale cultivation. One should consider abandoning treatments if pests do not appear in large numbers and are accompanied by the occurrence of beneficial species. Consideration should be given to limiting the treatment area to edges or patches if the pest is not present on the entire plantation. The use of tested mixtures of plant protection products and liquid fertilisers should be recommended, which reduces the number of entries into the field and reduces mechanical damage to plants;
- protection of beneficial species by avoiding the use of insecticides with a broad spectrum of activity and replacing them with selective agents;
- the timing of the treatment is selected to prevent poisoning and high mortality among beneficial insects;
- based on the results of studies, dose reduction and adjuvant addition;
- constant awareness that protecting natural enemies of triticale pests also protects other beneficial species present in the field;
- leaving furrows, field margin strips as a habitat for many species of beneficial insects;
- reading carefully the content of the label accompanying each plant protection product and observing the information contained therein.

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

9. PROPER SELECTION OF PLANT PROTECTION TECHNIQUES

Storage of plant protection products

Plant protection products should be stored:

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

b) in a manner ensuring that they:

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

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

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

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

Requirements for professional users

Persons or sprayer operators handling plant protection products must be suitably qualified 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 acquired rights to carry out plant protection treatments.

The sprayer operator must be equipped with appropriate protective clothing, as prescribed by the label and the safety data sheet of the plant protection product. The basic equipment of protective clothing includes: a suit, suitable shoes, rubber gloves resistant to plant protection products, glasses and mask to protect the eyes, respiratory system and covering the mouth. Proper 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**.

Apparatus and equipment for protective treatments

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

Equipment used for plant protection treatments must be safe for people and the environment. In addition, it should guarantee the full effectiveness of the protective treatments by ensuring proper operation, allowing accurate dosing and even distribution of the 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, sprayers, field beam, measuring and control devices, liquid system and agitator. It is also advisable to carry out a preventive rinse of the sprayer to remove mechanical debris and any residues of previous treatments from the system.

Calibration (adjustment) of the sprayer

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

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

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

Choice of plant protection product and dosage

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

Treatments with plant protection products should be planned to ensure acceptable efficacy with the minimum necessary amount of plant protection product applied, 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 stage of plants, their condition and climatic and soil conditions: wind, temperature and humidity of soil and air, type of soil as well as the content of organic matter in the soil.

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

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

- **time intervals between treatments,**
- **the maximum number of times the product can be used during the season,**
- **the maximum dose of the plant protection product.**

Spray volume selection

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

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 appropriate treatment equipment (e.g. AAS sprayers), the liquid dose can be reduced to 50-100 l/ha, which should guarantee a sufficient quality of treatment coverage on plants.

Selection of sprayers

Sprayers have a direct impact on the quality of spraying and thus on the safety and effectiveness of plant protection products. Catalogues and general recommendations for their use in the protection of agricultural crops are useful in selecting the right nozzles for particular 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 the spray liquid

The planned volume of the spray liquid should be made up immediately before treatment to avoid undesirable physico-chemical reactions. The agitator of the sprayer must be speedwelled on at all times to prevent the mixture from precipitating at the bottom of the tank. Before pouring the product into the tank, it is necessary to read the indications on the label as to the method of preparation of the spray liquid and the possibility of mixing the product with other preparations, adjuvants or fertilisers.

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

Sprayer filling:

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

Combined use of agrochemicals

In treatments with the use of several agrochemicals, the order of adding ingredients during the preparation of the spray liquid should be observed. A weighed portion of fertiliser (e.g. urea, magnesium sulphate) is poured into the sprayer tank half filled with water with the stirrer on. Further components are added to this solution. It is recommended that they be pre-diluted before pouring into the sprayer tank. Start with an adjuvant that improves compatibility of the components of the mixture, if used. Then plant protection products are added (in the correct order – according to the formulation) and supplemented with water to the desired volume of the sprayer tank.

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

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

Treatment conditions

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

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

Table 26. shows recommendations for optimum 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 data are included in the label texts. For most preparations, their optimal effectiveness is achieved at a temperature of 12-20 °C.

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

Table 26. Limit and optimal meteorological conditions for plant protection treatments

Parameter	Limits values (extreme)	Optimal values (most favourable)
Temperature	1-25 °C during treatment	12-20 °C during treatment
	up to 25 °C the day after treatment	20 °C on the day after
	not less than 1 °C the following night	not less than 1 °C the following
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 treatment	
Wind speed	0.0-4.0 m/s	0.5-1.5 m/s

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

- 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 over the field should be made very precisely to avoid unsprayed strips and so that no overlapping of the sprayed liquid occurs in already sprayed areas.

Post-treatment procedure

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

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

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

Procedure for rinsing the tank and liquid system

- for rinsing, use the least necessary amount of water (2-10 % of the volume of the tank or the amount up to 10 times dilution remaining in the liquid tank) — 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 to use the residue, according to the recommendations on the management of liquid residues,
- the residual liquid drained from the sprayer shall 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 for that purpose.

External sprayer washing

After the end of the working day, wash all the apparatus from the outside with water, as well as components in contact with chemical agents.

external sprayer washing should be carried out in a place that allows rinsing into a closed collection system for contaminated residues or to a neutralisation/bioremediation system (e.g. biobed, Phytobac, Vertibac); if this is not possible, it is best to wash the sprayer in the field.

Wash the sprayer with a small amount of water, preferably using a high-pressure lance instead of a brush to shorten the time and increase the efficiency of external washing.

Use recommended, biodegradable means to increase washing efficiency.

Registration of treatments

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

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

The law also requires the method of fulfilling the requirements of integrated plant protection to be indicated in the documentation by providing at least the reason for the treatment with a plant protection product. **Filling the mandatory IP notebook in the system of integrated plant production fulfils the requirement to keep the above-mentioned documentation for certified crops.**

10. HYGIENE AND HEALTH PRINCIPLES

Personal hygiene of employees

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

a) be free of food-borne infections or diseases;
b) maintain personal cleanliness, obey the rules of hygiene, and in particular often wash hands during work;
c) wear clean clothes and, where necessary, protective clothing;
d) injuries and abrasions should be treated 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 been trained in hygiene.

Hygiene requirements for crops prepared for sale

The plant producer shall take appropriate measures to ensure that:

a) clean water or consumption-grade water is used to wash agricultural produce as required;
b) crops are protected against physical, chemical and biological pollution during and after harvesting.

Hygiene requirements in the integrated system of crop production for packaging and means of transport and places for preparing crops for sale

A producer in an Integrated Crop Production system shall take appropriate measures to ensure that:

a) the rooms (including equipment), means of transport and packaging are kept clean;
b) farmed and domestic animals have no access to the rooms, vehicles and packaging;
c) harmful organisms (pests and organisms dangerous to humans), which may lead to contamination or pose a threat to human health, e.g. mycotoxins, are eliminated;
d) hazardous waste and substances are not stored together with crops prepared for sale.

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

Proper preparation of plantations for triticale harvesting significantly facilitates the work of combine harvesters, shortens harvesting time, reduces the number of machine failures, and increases work safety. For efficient harvesting, it is important to set the harvester, which affects the achievement of satisfactory results, including purely threshed, undamaged grain and the smallest possible losses. The quality of the grain is also affected by its efficient transport to the storage place. The best possible storage conditions should be created to ensure high quality and feed suitability of triticale grain.

Harvest time

Harvesting triticale with a combine harvester can begin at full maturity, when the caryopses are already hard and contain less than 17 % water. However, grains with humidity above 14.5 % need to be dried. **Therefore, the best time to harvest triticale is at the over-ripe stage, when the plants die and dry out. The caryopses are then very hard, and the water content in them falls below 14 %.** However, it should be borne in mind that with too low grain humidity (approx. 12 % and less), the greatest damage is caused to them.

An important principle of rational collection is to carry it out in the shortest possible time. In the first place, especially in wet weather conditions, grain intended for seed should be harvested due to the risk of overgrowing or developing fungi. Too early, the harvesting aggravates the conditions of its threshing and cleaning, reduces harvesting efficiency, increases fuel consumption, and can lead to greater expenditure on grain maintenance. However, harvesting too late increases grain loss. In addition, it must be taken into account that triticale sprouts relatively easily (Bieniek 2011; Przybył and Sęk 2010).

Preparation of the field for harvesting

Preparation of the field for harvesting determines the possibility of proper use of combine harvesters (Przybył and Sęk 2010). Proper preparation of the field surfaces is essential. The increase in the efficiency of combine harvesters is associated with an increase in their working width. Working with combine harvesters on fields with uneven surfaces (grooves, ruts, ridges, etc.) is difficult. Therefore, levelling the surface of the fields and collecting stones before sowing allows for the use of higher working speeds and a reduction in cutting height. Before harvesting, obstacles that are difficult for the harvester operator to notice, such as wetlands, concrete surveying posts, and drainage wells, should be marked, and the edges of the fields cleaned.

Access roads to fields, bridges, and culverts should be repaired and correspond to the dimensions and weight of the harvester or means of transport. It should be noted whether it is possible to reach the field at all with a combine harvester, as well as whether there is enough room for manoeuvring to attach the harvesting instrument.

It is also necessary to check the technical condition of all machines and equipment included in the process line for grain collection and post-harvest management to ensure that, in the event of any device becoming unsuitable, it will be possible to repair it in a short time.

Work organisation during harvesting

The harvester should be fully technically operational before starting the harvesting. In particular, the condition of the threshing unit should be checked. Worn out flails and tick lead to a decrease in the quality of the hammer. In order to reduce losses and excessive contamination of grain, appropriate adjustments of the harvester must be carried out.

Theoretically, the setting of the harvester for operation is provided in the operating manual. Notwithstanding this, the parameters specified by the manufacturer should only be considered as the starting point for the detailed adjustments set by the machine operator. In particular, it should be taken into account that the amount of damage and grain loss during threshing is also determined by the choice of threshing drum speed and the adjustment of the releasing and cleaning system.

When organizing the work of the harvester, it is necessary to choose the method of movement of the harvester. A bed-type movement of the harvester, parallel to the direction of sowing, should be aimed for, to allow a higher working speed to be obtained as the harvester does not have to overcome lateral bumps in the field. Circular motion is recommended in small fields of irregular shapes where it is impossible to move through using the bed-type movement.

With the bed-type movement of the harvester, large fields should be divided into beds. The width of beds should meet the aim of minimising the time lost on idle rides when turning back, while the width of the headland should ensure the possibility of easy turning back. The width of the first strip should be ten times the size of the working width of the harvester, and the subsequent strips 20 times.

Organisation of the work during grain harvesting at collecting it from the harvester and transporting it to the storage area has a significant influence on the actual performance of the harvester. Therefore, it is necessary to ensure the number and type of means of transport that should facilitate the collection of grain from the harvester at its maximum effective capacity, which usually occurs in the afternoon. If the harvested grain needs to be dried, a different work organization can be established. Then the efficiency of the entire grain harvesting process is determined by the efficiency of the drying unit. This can mean a reduction in the efficiency of the harvester and an increase in harvesting costs.

Load compartments of means of transport should be properly sealed and prepared for the transport of grain. Inadequate preparation of the trailer, e.g. inaccurately closing sides or gaps at the point of their contact with the floor, leads to large grain losses (Dreszer et al. 1998; Przybył and Sęk 2010).

Seed stores should provide optimal conditions for receiving a specified quantity of grain directly from the harvesters. The capacity of the grain intake process line should include a reserve of approximately 20 % in relation to the maximum operational efficiency of combine harvesters, in order to overcome potential bottlenecks in deliveries. The capacity of the unloading basket shall be such as to enable the entire contents of the means of transport to be received and the unloading to continue. The parking time of trailers at the warehouse should be limited to the minimum necessary for unloading.

Factors determining the storage of grain

The most important factors determining the proper storage of triticale grain are: cleanliness, adequate humidity, temperature, limiting air access, and protection against mechanical and organic damage (Kaleta and Górnicki 2008). In storage, the degree of physical damage to the caryopses is also important. Damaged caryopses are more easily infested by fungi, bacteria, arachnids, and insects than whole grains. The greater the degree of damage to the caryopses, the greater the possibility of spoilage of the grain during storage. Therefore, by creating appropriate storage conditions, the quality of the grain should be ensured, including the elimination of the development of undesirable microflora, especially fungi.

After harvesting, the grain should be cleaned. Grain harvested with a combine harvester is characterized by a relatively high temperature, often exceeding 30°C, and impurities in the form of green plant parts, weed seeds, and straw, which have higher moisture content than the grain itself. Contaminants primarily increase the moisture content of the grain and promote its self-heating, which causes irreversible deterioration of its quality. The use of cleaning treatment reduces grain moisture by up to a few percent (Ryniecki and Szymański 1999).

Triticale grain, if it is to be stored for more than 6 months, should contain a maximum of 13 % water (Kaleta and Górnicki, 2008). At higher humidity, it is necessary to dry it.

12. DEVELOPMENT STAGES OF TRITICALE BASED ON THE BBCH SCALE

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

CODE DESCRIPTION

Principal growth stage 0: Germination

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

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

10 First leaf through coleoptile (pinning)
11 1st leaf unfolded
12 2nd leaf unfolded
13 3rd leaf unfolded
14 4th leaf unfolded
15 5th leaf unfolded
1. These stages continue until...
19 9 or more leaves unfolded

Principal growth stage 2: Tillering

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

Principal growth stage 3: Stem elongation

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

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

41 Beginning of thickening (swelling) of the flag leaf sheath, early stage of ear development
43 Mid boot stage: flag leaf sheath just visibly swollen
45 Final stage of swelling of the flag leaf sheath, late stage of ear development
47 Flag leaf sheath opening
49 First awns visible

Principal growth stage 5: Heading

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

Principal growth stage 6: Flowering

61 Beginning of the flowering stage: first anthers visible

65 Full flowering: 50 % of anthers mature 67

69 End of flowering: all the spikelets have completed flowering but some dehydrated anthers may remain

Principal growth stage 7: Development of fruit

71 Water maturity: the first watery caryopses have reached half their typical size

73 Early milk

75 Medium milk: grain content milky, caryopses reached final size, still green

77 Late milk

Principal growth stage 8: Ripening

83 Beginning of waxy maturity of the caryopses

85 Soft waxy maturity, caryopses easily smeared between the fingers

87 Hard waxy maturity, caryopses easily broken with a fingernail

89 Full maturity, hard grains, difficult to split with a fingernail

Principal growth stage 9: Senescence

92 Over-ripe: very hard caryopses, cannot be dented by a fingernail

93 Caryopses loose in the ear, may fall off

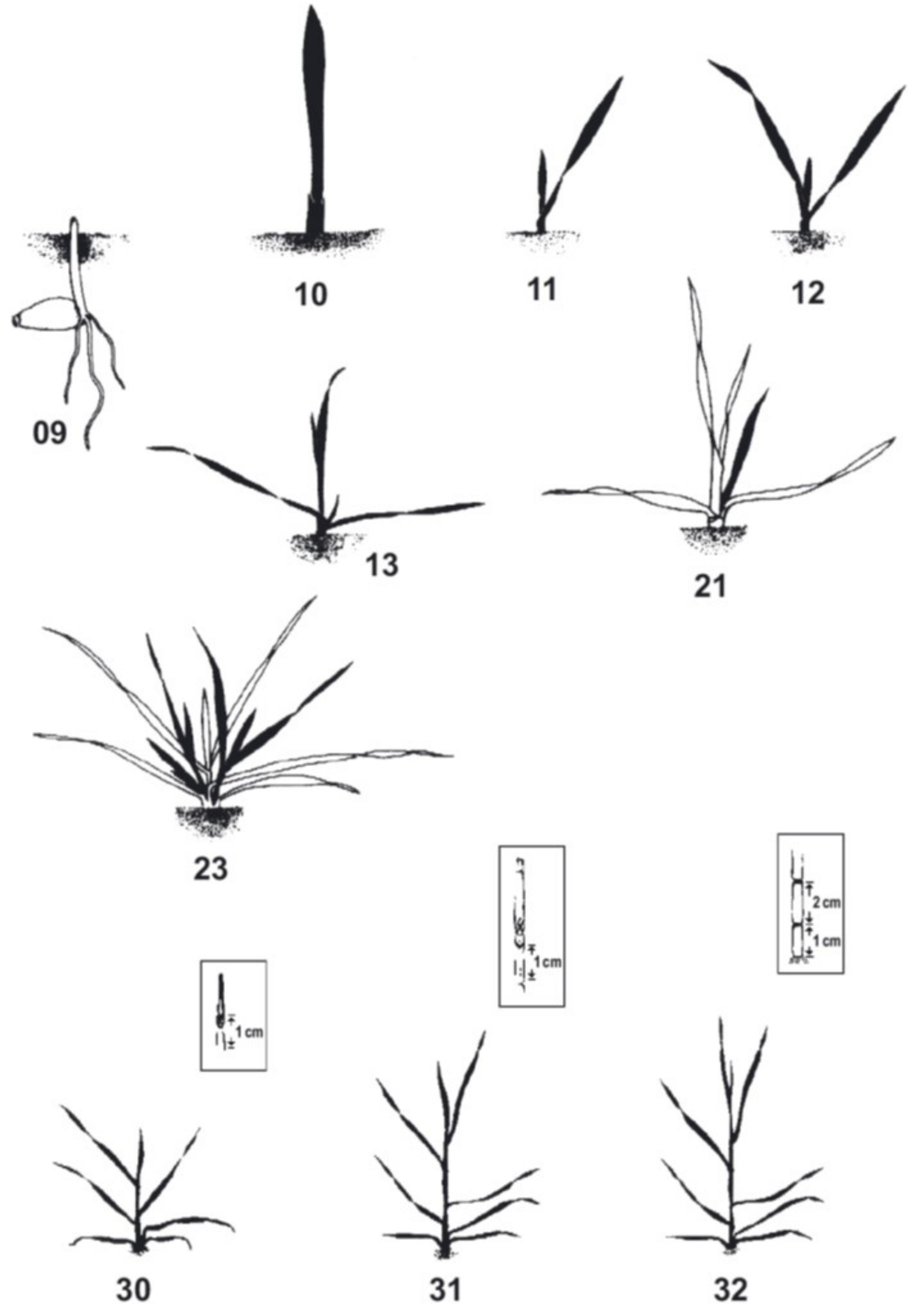
97 Plant dead and collapsing

99 Harvested product, resting period

[1] A leaf may be described as unfolded when its ligule is visible or the tip of the next leaf is visible

[2] Tillering or stem elongation may occur earlier than in stage 13, then the description is continued in stage 21

[3] If the stem elongation stage begins before the end of the tillering stage, then the description is continued in stage 30.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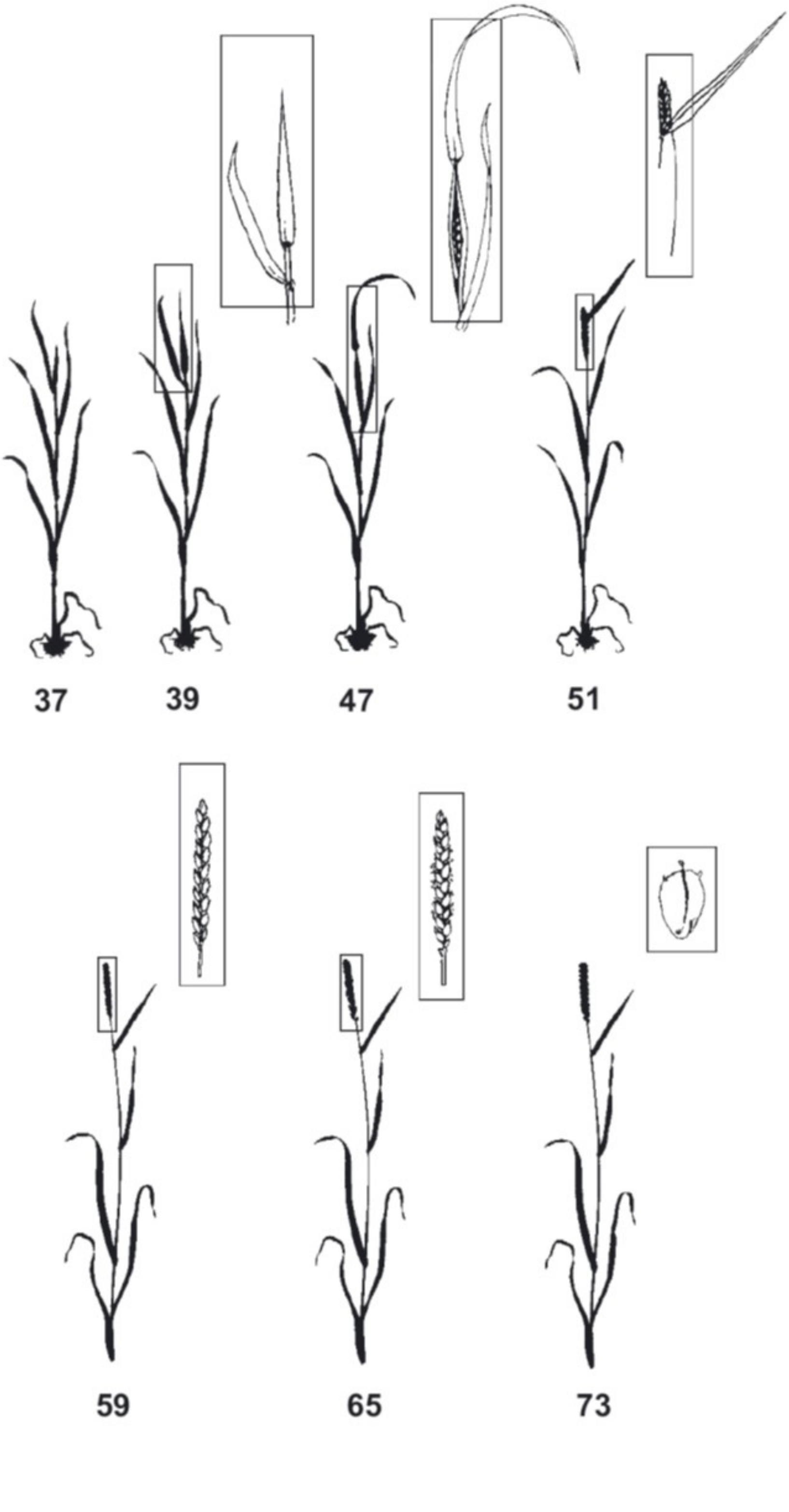
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13. RULES FOR KEEPING RECORDS IN INTEGRATED PRODUCTION

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

Other documents that a producer using integrated plant production must have or may deal with during the certification process include:

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

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

The application form should be completed with information such as:

- the name, address and place of residence or the name, address and registered office of the plant producer;
- the PESEL (personal identification) number, if one has been assigned to them.

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

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

The notebook should be filled in according to the following outline.

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

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

Field plan with biodiversity-increasing elements —graphically reproduce the plan of the holding and its immediate surroundings with the proportions of the various elements. On the farm plan, use the markings used as in the list of fields.

General information, sprayers, operators – enter the year in which the production started according to the principles of integrated plant production. Then move on to completing the table. Fill in the bulleted places with appropriate entries and confirm the information by ticking the boxes prepared for this purpose (   ). The 'Sprayers' table should be filled in with the required data and the information confirmed by ticking the relevant boxes (□). Note all sprayers operators carrying out plant protection treatments in the 'Sprayer operator(s)' table. It is absolutely necessary to indicate that the training in the use of plant protection products is up to date, including the date of completion (or other qualification). In the 'Sprayers' and 'Sprayer operator(s)' tables, all devices and persons performing treatments, including those performed by a service provider, are listed.

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

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

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

Seed (…) – the table should be completed by entering information about the purchased seed – species, variety, category, degree of qualification, quantity, and proof of purchase (invoice, official label, or marketing label).

Sowing/Planting – the table should contain the quantity of seed used in each field. The dates of the activities carried out should also be recorded. Information on soil testing/assessment for existing pests that exclude the field from IP cultivation should be confirmed by ticking the relevant boxes (□).

Soil/substrate and plant analysis and fertilisation/fertigation — soil analysis is a fundamental activity to determine the fertiliser needs of plants. The IP producer must carry out such analyses and record them in the notebook. The field code, the type or scope of testing and the number and date of the report should be entered in the 'Soil and plant analysis' table. All organic fertilisers applied should be recorded in the 'Organic fertilisation (…)' table. If green manures are used, the species or composition of the mixture is indicated in the 'Type of fertiliser' column. In the next table, 'Soil mineral fertilisation and liming', note the date and type and dose of fertilisation and liming applied and where it was applied. The 'Observations of physiological disorders and foliar fertilisation' table should be used to record observations regarding plant nutritional deficiencies and fertilisers applied. The IP grower must regularly inspect the crops for the occurrence of physiological diseases and record this fact each time. Foliar fertilisation should be correlated with the observations of physiological disorders carried out.

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

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

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

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

Information on the cleaning of machinery, devices and equipment used in production, according to the requirements of the integrated production methodology – notebook page with the IP producer's space for information relating to the cleaning of machinery, devices and equipment used in the production, which is required in the integrated production methodology.

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

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

LIST OF OBLIGATORY ACTIVITIES AND TREATMENTS IN INTEGRATED PRODUCTION (IP) OF TRITICALE

Mandatory requirements (100 % compliance, i.e. 14 points)			
No.	**Checkpoints**	**YES/NO**	**Comment**
1.	Implementing appropriate crop rotation — indicated in the methodology (**see chapter 3.3.**)	☐/☐	
2.	Selection of varieties recommended by COBORU (**see chapter**). **4**)	☐/☐	
3.	Use of certified and treated seed in accordance with the ESTA standard or equivalent – certified seeds (**chapter 5.2.**)	☐/☐	

4.	Analysing soil pH and the content of the main nutrients (NPK and Mg) according to the cycles indicated in the methodology confirmed by documents (**see chapter 6.**)	□/□	
5.	Application of macro- and micronutrient fertilisation at the appropriate times and doses, depending on the type and pH of the soil, following a nutrient balance carried out according to the indications in the methodology (**see chapter 6.**)	□/□	
6.	Use of agrotechnical methods as the first step in weed control and, in the case of chemical control, the correct application of herbicide at the right dose, taking into account the level of susceptibility of the weeds determined for individual weeds or their groupings (**see chapter 7.1.**)	□/□	
7.	Monitoring of the field during the tillering/stem elongation stage, the flag leaf stage, and heading to assess the occurrence of diseases (powdery mildew of cereals and grass, septoria nodorum blotch - symptoms on the leaves, brown rust, brown leaf spot, yellow rust) and after heading, with particular emphasis on fusarium ear blight (**see chapter 7.2.**)	□/□	
8.	Systematic monitoring of the field from emergence to tillering once per week for the presence of aphids – virus vectors, and from the beginning of the heading, to maturation, observation for the presence of cereal leaf beetles and gall midges once every two weeks (direct plant inspection, yellow traps, etc.) (**see chapter 7.3.)**	□/□	
9.	Once the pest and disease threshold is exceeded, the use of plant protection products (using the Pest Warning System or other decision support systems) (**see chapter 7.2.4. and 7.3.2.**)	□/□	
10.	Use of only plant protection products from the list of products authorised for use in the integrated production of triticale (**see chapter 7.**)	□/□	
11.	Creating suitable conditions for the presence of birds of prey, i.e. setting up resting poles in the amount of at least 1 per 5 ha, and in the case of larger plantations – several units (**see chapter 8.**).	□/□	
12.	Placing of ‘houses’ for mason bees or mounds for bumblebees or other insect pollinators at a frequency of at least 1 pc for every 5 ha (**see chapter 8.**).	□/□	

13.	Alternate use of active substances of plant protection products from different chemical groups to prevent the resistance of pests (weeds, pathogens) (**see chapter 7.**)	☐/☐	
14.	Harvesting at the right time (correct grain moisture) (**see chapter 11.**)	☐/☐	

Note:

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

14. CHECKLIST FOR AGRICULTURAL CROPS

Basic requirements (100 % compliance, i.e. 28 points)			
No.	Checkpoints	YES/NO	Comment
1.	Does the producer produce and protect the crops according to detailed methodologies approved by the Main Inspector?	☐/☐	
2.	Does the producer have up-to-date IP training confirmed by a certificate, subject to Articles 64(4), (5), (7) and (8) of the Plant Protection Products Act?	☐/☐	
3.	Does the producer apply plant protection products only from the list of IP-recommended products?	☐/☐	
4.	Are all required documents (e.g. methodologies, notebooks) present and kept on the farm?	☐/☐	
5.	Is the IP notebook kept correctly and up to date?	☐/☐	
6.	Does the producer systematically conduct control observations of the crops and record them in the notebook?	☐/☐	
7.	Does the producer deal with empty packaging of plant protection products and products that are out of date in accordance with the applicable legal regulations?	☐/☐	
8.	Is chemical protection of crops replaced by alternative methods wherever justified?	☐/☐	
9.	Is chemical plant protection carried out based on risk thresholds and the alerts of harmful organisms (wherever possible)?	☐/☐	

Basic requirements (100 % compliance, i.e. 28 points)			
10.	Are procedures using plant protection products carried out only by persons having an up-to-date, as of the date of such procedures, certificate on the completion of training in the scope of the application of plant protection products or advisory on plant protection products, or integrated plant production, or any other document confirming the right to apply plant protection products?	□/□	
11.	Are the applied plant protection products approved for use in the plant?	□/□	
12.	Is each use of plant protection products recorded in the IP notebook taking into account the reason, date and place of use, the area of the crops, the dosage and the amount of the spray liquid per unit of area?	□/□	
13.	Were the plant protection treatments carried out under appropriate conditions (optimal temperature, wind below 4 m/s)?	□/□	
14.	Is the rotation of the active substances of the plant protection products used for the treatments respected, if possible?	□/□	
15.	Does the producer limit the number of treatments and the amount of plant protection products used to a necessary minimum?	□/□	
16.	Does the producer have measuring devices to precisely determine the quantity of the measured plant protection agent?	□/□	
17.	Are the conditions for safe use of the agents respected, as set out on the labels?	□/□	
18.	Does the producer comply with the provisions of the label concerning the observance of precautions related to environmental protection, i.e. e.g. the observance of protective zones and safe distance from areas not used for agricultural purposes?	□/□	
19.	Are prevention and withdrawal periods observed?	□/□	
20.	Are the doses and maximum number of treatments per growing season specified on the label of the plant protection product not exceeded?	□/□	
21.	Are the sprayers referred to in the IP notebook in	□/□	

Basic requirements (100 % compliance, i.e. 28 points)			
	good technical condition and are their technical inspection certificates up to date?		
22.	Does the producer carry out systematic calibration of the sprayer(s)?	☐/☐	
23.	Does the producer have a separate space for filling and cleaning the sprayers?	☐/☐	
24.	Does the handling of residues of the spray liquid comply with the indications on plant protection product labels?	☐/☐	
25.	Are plant protection products stored in a marked closed room in such a way as to prevent contamination of the environment?	☐/☐	
26.	Are all plant protection products stored only in their original packaging?	☐/☐	
27.	Does the IP producer observe hygienic and sanitary principles, especially those specified in the methodologies?	☐/☐	
28.	Are appropriate conditions for the development and protection of beneficial organisms ensured?	☐/☐	
	Total points		

Additional requirements for field vegetable crops (minimum compliance 50 %, i.e. 8 points)			
No.	**Checkpoints**	**YES/NO**	**Comment**
1.	Were the plant varieties grown selected for Integrated Plant Production?	☐/☐	
2.	Is each box marked according to the entry in the IP notebook?	☐/☐	
3.	Did the producer perform all the necessary agrotechnical procedures in accordance with IP methodologies?	☐/☐	
4.	Is the recommended catch crop used in cultivation?	☐/☐	
5.	Are steps taken on the holding to reduce soil erosion?	☐/☐	
6.	Have the procedures been conducted using	☐/☐	

	spraying devices specified in the IP notebook?		
7.	Are fertiliser application machines maintained in good working order?	☐/☐	
8.	Do fertiliser application machines allow for accurate dose determination?	☐/☐	
9.	Is each fertiliser applied recorded with regard to its form, type, date of application, quantity, location and surface?	☐/☐	
10.	Are fertilisers stored in a separate and specially designated room in a manner that ensures protection of the environment against contamination?	☐/☐	
11.	Does the producer protect empty PPP packaging against unauthorised access?	☐/☐	
12.	Does the producer have a dedicated place to collect organic and post-vegetable-sorting residues?	☐/☐	
13.	Are there first-aid kits near the workplace?	☐/☐	
14.	Are hazardous areas on the farm, e.g. plant protection product storage rooms, clearly marked?	☐/☐	
15.	Does the producer use consultancy services?	☐/☐	
	Total points		

Recommendations (min. implementation 20 %, i.e. 2 points)			
No.	**Checkpoints**	**YES/NO**	**Comment**
1.	Are soil maps drawn up for the farm?	☐/☐	
2.	Are inorganic 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.	Does the lighting in the room where the plant protection products are stored make it possible to read the information on the packaging of the plant protection products?	☐/☐	
5.	Does the producer know how to proceed in the event of spill or scatter of plant protection products and do they have tools to counteract	☐/☐	

	such a threat?		
6.	Does the producer restrict access to the keys and the warehouse in which the plant protection products are stored, to persons who do not have the authority to use them?	☐/☐	
7.	Does the producer store on the farm only plant protection products allowed for use with the plant species they cultivate?	☐/☐	
8.	Does the producer improve their knowledge at integrated plant production meetings, courses or conferences?	☐/☐	
	Total points		

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