MAIN INSPECTORATE OF PLANT HEALTH AND SEED INSPECTION

DRAFT

Methodology for the Integrated Production of Lentils (*Lens culinaris Medic*) (first edition)

Approved

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

by
the Main Inspector of Plant Health and Seed Protection

Warsaw, February 2025

Approved by
~~/signed electronically/~~

Institute of Soil Science and Plant Cultivation — State Research Institute
ul. Czartoryskich 8, 24-100 Puławy
tel. 814 786 700, e-mail: iung@iung.pulawy.pl www.iung.pl

Collective study edited by Prof. Jerzy Księżak

Authors:

Dr Jolanta Bojarszczuk[1]
Dr Karolina Furtak[1]
Dr Grzegorz Gorzała[4]
Dr Joanna Horoszkiewicz[2]
Prof. Marek Korbas[2]
Prof. Roman Kierzek[2]
Prof. Marcin Kozak[3]
Prof. Jerzy Szwejda[1]
Dr Tomasz Sekutowski[1]
Dr Przemysław Strażyński[2]
Prof. Danuta Sosnowska[2]

[1] Institute of Soil Science and Plant Cultivation — State Research Institute in Puławy
[2] Institute of Plant Protection – National Research Institute, Poznań
[3] Wrocław University of Life Sciences
[4] Main Inspectorate of Plant Health and Seed Protection, Warsaw

Reviewer - Prof. Renata Tobiasz–Salach

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1. PREFACE

Lentils (*Lens culinaris* Medic) belong to the legume family, the leguminous tribe. It is a very popular species in Western Europe (Spain), the United States and the Middle East (Syria, Iran, Pakistan, Lebanon). In Poland, before the Second World War, lentils were grown on an area of approximately 1 400 hectares. The unreliable yielding of this species, the competition of prolific species and the lack of valuable domestic varieties meant that as our agriculture intensified, lentils were almost completely displaced from field cultivation, they were cultivated solely on small areas for own use. Interest in lentil cultivation has increased in recent years. According to the data of the Agency for Restructuring and Modernisation of Agriculture (ARiMR), lentils are cultivated on an area of 38 400 hectares. (ARiMR 2024). Next to peas, lentils are one of the oldest and most valuable high-protein crop species (Piróg 2003). This is determined by the dietary value of their seeds, as well as by the high feed value of silage and straw. The seeds of this species contain the least antinutritional substances of all legumes (Hefnawy 2011). These are mainly compounds from the oligosaccharide group: stachyose, raffinose and verbascose. This species is also valued for the high nutritional value of its seeds. It is rich in protein (24-32%), carbohydrates, and has significant amounts of certain vitamins, mainly from group B, as well as macronutrients, inter alia, phosphorus, potassium, magnesium, iron and sodium. The seeds are characterised by a high proportion of exogenous amino acids, especially lysine, leucine, arginine, histidine and valine (Costa et al. 2006, Joshi et al. 2017, Kowalczyk et al. 2007, Kahraman 2016, Karadavut and Genc 2010, Hamdi et al. 2012, Wang 2008, Wang 2009). They also have antioxidant properties (Szwejkowska 2012). The nutritional content of the seeds depends largely on genetic and environmental factors (Erskine and Sarker 2004). Lentils have a high nutritional value, both as human food and animal feed (Erskine and Sarker 2004). In addition, lentils play an important role in crop rotation, especially in organic farming (Gan et al. 2003, Sellami et al. 2019, Bicer 2014).

Despite the many beneficial properties of lentils, the growing area of this species is relatively small. This is mainly due to their limp stems, that are highly prone to lodging, and low competitiveness to weeds (Chaudhary et al. 2011). One of the ways to reduce lentil lodging is companion planting with other plant species (Deuchene et al. 2017, Zawieja 2006, Żabiński 2008). In the organic farming system, where the use of chemical plant protection products is prohibited, it is important to implement other solutions that reduce weed infestation (Bond and Grundy 2001). According to Duer (2002), Vlachostergios and Roupakias (2008), Avola et al. (2008), these may be companion planting, appropriately selected crop rotation, diversified agrotechnology, selection of varieties adapted to soil and climate conditions with greater competitiveness to undesirable species.

Cultivated lentil varieties belong to two subspecies differentiated on the basis of seed size: the small-seeded form with a TSW of about 30 g and the large-seeded form with a TSW of about 60 g. The plant develops a fairly short, thin taproot with a well-developed mass of lateral roots. In addition, thanks to its symbiosis with the *Rhizobium leguminosarum* bacteria, which inhabit nodules located on the lateral roots, it has the ability to fix atmospheric nitrogen.

The high usability assessment of lentils, their small soil, fertiliser and water requirements all speak for the desirability of expanding their cultivation in our country.

2. LEGAL PROVISIONS APPLICABLE TO INTEGRATED PRODUCTION AND IP CERTIFICATION RULES

2.1. Integrated plant protection

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

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

Professional users who use plant protection products are obliged to take into account the requirements of integrated plant protection set out in the Regulation of the Minister for Agriculture and Rural Development of 18 April 2013 on requirements for integrated plant protection (Journal of Laws, item 505). According to the above-mentioned Regulation, an agricultural producer should use all available measures and methods of protection against pests before applying chemical plant protection in order 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 agrotechnical deadlines, the use of appropriate agrotechnology, fertilisation, and prevention of the spread of harmful organisms. One of the requirements also consists in the protection of beneficial organisms and the creation of favourable conditions for their occurrence. This particularly applies to pollinators and natural enemies of harmful organisms. The use of chemical plant protection should be preceded by monitoring activities and supported by appropriate scientific instruments and advice.

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

The list of plant protection products authorised in Poland is published in the register of plant protection products. Information on the extent of pesticide use in particular crops is placed on the labels. The Ministry of Agriculture and Rural Development makes the register and labels available at https://www.gov.pl/web/rolnictwo/ochrona-roslin.

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

The method of application must be fully consistent with the instructions on the label. Plant protection products may only be used on plants and pests which are specified on the label. The indicated doses and the number of authorised treatments must not be exceeded. Plant protection products must be applied only to the areas and facilities targeted by the treatment, i.e. they must not be drifted during application.

When planning the use of pesticides, it should be borne in mind that there may be areas on the farm where the use of plant protection products is restricted or completely prohibited.

Such areas are most often designated in the vicinity of water bodies and watercourses and in non-agricultural areas. Buffer zones may also be designated, inter alia, for the protection of non-target plants and arthropods.

In the case of a demarcated buffer zone (information on the label of the plant protection product), the part of the crop directly adjacent to the site from which that zone has been demarcated may not be protected by that measure. In terms of maintaining minimum distances from specific places or facilities (e.g. apiaries), professional users are also bound by the provisions of the Regulation of the Minister for Agriculture and Rural Development of 31 March 2014 on the conditions of use of plant protection products.

Persons using plant protection products must have received appropriate training in the use of plant protection products, attested by a certificate of completion. Plant protection products may also be used by persons who have received training in PPP consulting, integrated production of plants, or who possess the qualifications referred to in Article 64 of the Plant Protection Products Act of 8 March 2013.

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

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

2.2. Integrated plant production

Integrated Plant Production is an extension of Integrated Plant Protection. It is based directly on the concept and requirements of integrated plant protection.

Integrated Plant Production is a voluntary food quality certification scheme in Poland, participation in which is conditional on the annual notification of crops to the certification body by the agricultural producer.

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

Detailed legal regulations concerning IP are contained in Chapter 6. Integrated plant production is based on the Plant Protection Products Act of 8 March 2013. Technical provisions in the integrated production system are IP methodologies approved by the Main Inspector of Plant Health and Seed Protection and published on the website administered by the Main Inspectorate of Plant Health and Seed Protection (https://www.gov.pl/web/piorin/metodyki-ip).

In integrated plant production, the principle of limited selection of plant protection products applies. The list of plant protection products permitted in integrated production is published on the Pest Signalling Platform at https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.html.

2.3. Certification rules

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

The notification of the intention to use integrated plant production shall be made annually by the plant producer concerned to the certification body, **within the time limit laid down in Article 55(2) of the Plant Protection Products Act of 8 March 2013.** The integrated plant production 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 the 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;
- compliance with the production methods approved by the Main Inspector of Plant Health and Seed Protection;
- fertilisation applied;
- keeping and maintaining records;
- following hygiene and health principles;
- collection of samples and control of highest tolerable plant protection product residues as well as of nitrate, nitrite and heavy metal levels in plants and plant products.

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

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

- has completed training in integrated plant production and holds a certificate of completion of that training, subject to Article 64(4), (5), (7) and (8) of the Plant Protection Products Act;
- produces and protects plants in line with the detailed methodology approved by the Main Inspector available on the website administered by the Main Inspectorate of Plant Health and Seed Inspection;
- uses fertilisation based on the actual plant nutritional needs determined on the basis of, in particular, the analysis of the soil and plants;
- documents the correct conduct of activities related to Integrated Plant Production;
- follows hygienic and sanitary rules in plant production, particularly those defined in methodologies;

- in plant and plant product samples collected for testing, no maximum permissible residues of plant protection products and levels of nitrates, nitrites and heavy metals have been exceeded;
- adheres to requirements concerning plant protection against harmful organisms, particularly those specified in methodologies, during plant production.

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.

A plant producer who has received a certificate certifying the use of integrated plant production may use the Integrated Plant Production Mark to label the plants for which this certificate was issued. The sample mark is made available by the Main Inspector on the website managed by the Main Inspectorate of Plant Health and Seed Inspection.

2.4. Hygiene and sanitary rules

During harvest and the preparation of crops produced under integrated plant production for sale, the producer ensures that the following health and hygiene rules are followed.

A. Personal hygiene of employees.

1. Persons working in the harvesting and preparation of crop for sale should:
   - not be infected with or suffer from food-borne diseases;
   - maintain personal hygiene, observe hygiene rules, and in particular wash their hands often during work;
   - wear clean clothing and, where necessary, protective clothing;
   - injuries and abrasions should be treated with a waterproof dressing.
2. The producer shall ensure persons involved in harvesting crops and preparing them for sale:
   - unlimited access to washbasins and toilets, cleaning products, paper towels or hand dryers, etc.;
   - training in hygiene.

B. Hygiene requirements for crops prepared for sale.

The crop producer should take appropriate measures to ensure:

- that clean or consumption-class water is used to wash the crops as necessary;
- the protection of crops during and after harvesting against physical, chemical, and biological pollution.

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

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

- cleanliness of rooms (and equipment), means of transport and packages is maintained;
- farm and domestic animals are not allowed into rooms, vehicles, and packages;
- pests are eliminated (plant pests and organisms hazardous to humans) that may cause emerging contamination or human health risks, e.g. mycotoxins;
- hazardous waste and substances are not stored together with crops prepared for sale.

3. AGRONOMIC REQUIREMENTS

3.1. Habitat requirements

Lentils are among the plant species that yield well in the continental climate, so in the past its cultivation has enjoyed greater interest in eastern and southern Poland. It is a species of the long day that reacts negatively to its shortening. In the early stages of plant development, the thermal requirements of lentils are slightly higher than that of peas.

Germination of the seeds begins at a temperature of 3-4 °C, and takes place at least 6 days after sowing, and emergence is observed 6-12 days after sowing. Vernalisation takes place at a temperature of 5-8°C and takes a relatively short time. The optimum temperature during the period of pod setting and seed ripening is about 19-20 °C, although in the period of germinating, lentils endure harmless short-lived frosts as sold as -6 °C. The sum of temperatures in the period from sowing to emergence should be 110-125 °C, from sowing to full flowering about 940 °C and from sowing to full maturity 1 500-1 800 °C.

Lentil water requirements are lower than those of other species of legumes. The most water is required during the period of seed swelling and germination (about 95% of water in relation to the dry mass of the seeds) and during the formation of flower buds and at the beginning of flowering. Lack of water during these periods causes uneven emergence, poor growth and worse pod formation. Lentils cope well with periodic water shortages, with fine-seeded forms being more resistant to drought than large-seeded forms. On the other hand, excess water is particularly harmful to the lentils during the ripening of the seeds. Heavy rainfall during this period results in stronger lodging and prolongs the growth of plants.

Lentils may be grown on soils suitable for forage peas or narrow-leaved lupin, which are included in the faulty, rye high-good and good wheat complex. It grows well on moderately supple lighter soils with good permeability and moderately moist soils. Growing on too fertile, nitrogen-rich soils causes excessive growth of the vegetative parts, prolonged flowering and delayed ripening. Soils should be in good agricultural condition and their air and water relations should be in order.

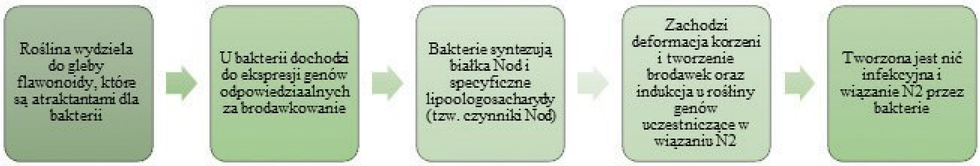
3.2. Crop rotation

The selection rules for lentils are similar to those for other legume species. The best pre-crops for this species are cereals grown 2-3 years after root crops and after manure fertilisation. The break in the cultivation of lentils in the same field should be no shorter than three years.

The site immediately after the root should be avoided, because under these conditions it produces excessive vegetative mass and often strongly overhangs, which is not conducive to seed production and exposes the plantation to stronger infestation by pathogens and pests. Due to the possibility of lowering the activity of root warts, lentils should not be grown after each other and after other species of legumes. It is also not recommended to grow lentils after other perennial legumes that can leave excess nitrogen in the soil. The site for growing lentils should also be carefully weeded, because the plant is sensitive to weeds. Cultivation of this species promotes the activity of biological life of the soil. The relatively strong root system contributes to the loosening of the subcutaneous layer and thus facilitates deeper rooting of follow-on plants and enriches the soil with nitrogen in the amount of 40 to 50 kg/ha-1. In addition, lentils improve the phytosanitary status of the soil, thereby reducing the infestation of follow-on plants (cereals) with soil-mediated diseases. Before establishing a plantation, it is beneficial to sow a post-harvest crop. It provides a large amount of organic matter, reduces field weeding and prevents nitrogen leaching into groundwater.

3.3. Biological nitrogen fixation

Legumes are characterised by the ability to biologically bind atmospheric nitrogen (N_2), which is transformed into biologically useful ammonia included in the biomass. Ammonia is assimilated by plants and converted into amino acids and other nitrogen compounds. Ammonium ions (NH_4^+) present in the soil are oxidised by nitrification to nitrites (NO_2^-) followed by nitrates (NO_3^-) which are again denitrified to N_2 by microbial route, closing the cycle. Biological nitrogen fixation takes place only with the participation of soil bacteria capable of binding nitrogen, using for this process nitrogenase, an enzyme responsible for reducing the nitrogen molecule (Pociejowska et al. 2013). Nitrogenase is only active under anaerobic or extreme oxygen conditions. Due to the symbiosis of legumes and rhizobia, nitrogen in the digestible form is transferred to the plant. Nitrogen-fixing bacteria in symbiosis with legumes are referred to as ‘rhizobia’. This name is derived from the name of the first bacteria analysed in this group – *Rhizobium*. Microorganisms with primary ability to bind N2 include: *Bradyrhizobium*, *Azorhizobium*, *Mesorhizobium*, *Rhizobium* and *Ensifer*. On the other hand, among those that have acquired these skills are: *Burkholderia*, *Devosia*, *Cupravidus*, *Ochrobactrum*, *Microvirga*, *Methylobacterium*, *Phyllobacterium* and *Shinella*. The group of these bacteria can also be called rhizobia, root or nitrogen bacteria. Rhizobia enter the roots through the so-called infectious thread and cause the formation of warts on the roots of plants as a result of very rapid multiplication in plant cells (Gnat et al. 2015). In these cells, rhizobia modify their metabolism, become bacteroides and begin to assimilate nitrogen, which takes place in several stages (Figure 1).



Roślina wydziela do gleby flawonoidy, które są atraktantami dla bakterii	The plant secretes flavonoids to the soil that are attractants for the bacteria
U bakterii dochodzi do ekspresji genów odpowiedzialnych za brodawkowanie	Bacteria express genes responsible for the nodulation
Bakterie syntezują białka Nod i specyficzne lipoologosacharydy (tzw. Czynniki Nod)	Bacteria synthesise nod proteins and specific lipoologosaccharides (so-called Nod factor)
Zachodzi deformacja korzeni i tworzenie brodawek oraz indukcja u rośliny genów uczestniczące w wiązaniu N2	Root deformity and wart formation and gene plant induction involved in N2 binding
Tworzona jest nic infekcyjna i wiązanie N2 przez bakterie	N2 infection thread is formed by the bacteria

Figure 1. Stages of biological nitrogen fixation (based on: Łyszcz and Gałązka 2016)

The host plant provides the bacteria with carbon compounds, carbohydrates and growth conditions, and the bacteria transfer NH_3 or glutamine to the plant cells (Trawczyński 2010). The pink colouration of the root papillary indicates an active nitrogen fixation process. This process is most intense before and during the flowering period of plants, and after its completion, symbiosis weakens. The symbiosis of bacteria with legumes is specific, because each species can only coexist with a specific species of rhizobia (Podleśna 2018). Plants are able to recognise a chemical signal from a given bacterial species and select an optimal symbiote (Heath and Tiffin 2009). In the case of lentils, the bacterial symbiote is *Rhizobium leguminosarum* bv. viceae (Table 1).

Table 1. Examples of legumes and their bacterial symbiotes

Species	Bacteria
Lupin Ornitho	*Bradyrhizobium sp.*
Soybean	*Bradyrhizobium japonicum*
Pea Green pea Broad bean Lentil Vetch	*Rhizobium leguminosarum* bv. viceae
Bean	*Rhizobium leguminosarum* bv. phaseoli
Clovers	*Rhizobium leguminosarum* bv. trifolii
Lucerne Melilot Fenugreek	*Sinorhizobium meliloti*
Birdsfoot trefoil	*Mesorhizobium loti*
Chickpea	*Mesorhizobium ciceri; Mesorhizobium*

In some soils rhizobia are abundant, but vaccination of legume seeds with vaccines containing symbiotic bacteria is justified (IUNG-PIB Guide 2023). The use of microbiological preparations containing rhizobia is indicated when:

- the legume species has not been cultivated in the area concerned for a long period (4-5 years);
- the soil has an acidic reaction;
- the area where the species is sown is to be reclaimed;
- we sow legumes on uncultivated agricultural land;
- a plant species that is not native, e.g. soya, is cultivated.

The vaccine should contain 10^7 - 10^9 colony-forming units (CFU) of live bacteria per 1 gram of preparation. In addition to the correct selection of the preparation for the species of sown plant, attention should be paid to the correct use of the preparation. Vaccines containing rhizobia are most commonly used by coating the seeds before sowing. Rhizobia are sensitive to light, therefore storage of the preparation in sunny areas should be avoided, encapsulation should be carried out as soon as possible and treated seeds should not be left in the light. Such a preparation should also not be frozen or exposed to high temperatures (above 40 °C). **If chemical treatment of plants, e.g. fungicides, is planned before sowing, then this treatment must be carried out first and the microbiological preparation must be applied afterwards** (Guide IUNG-PIB 2023).

Bacteria of the genus *Mesorhizobium*, mainly *M. ciceri* and *M. mediterraneum* (Wanjofu et al. 2022), are used to inoculate lentils. For this species, the symbiotic N_2 bond is most effective under neutral or slightly acidic soil conditions (Oparah et al. 2024). This process is also influenced by soil moisture and molybdenum (Mo) content, with their limited access, symbiosis is less efficient (Lusiba et al. 2022).

Of the estimated 139-170 million tonnes of nitrogen entering the global cycle annually, symbiotically fixed nitrogen accounts for 70-80%. It is also estimated that the symbiotic relationship of legumes with bacteria provides approximately 44-60 million tonnes of nitrogen per year, which constitutes almost half of the total amount used in agriculture. The ability to fix nitrogen varies depending on the plant species. In the case of lentils, the amount of nitrogen fixed from the atmosphere is in the range of 109-136 kg N/ha-1 (Table 2).

Table 2. Nitrogen fixation indices of selected legume species (based on various sources)

Species	**Amount of nitrogen fixed**
Chickpea	18-78 kg N/ha^{-1}
Lupin	43-130 kg N/ha^{-1}
Narrow-leaved lupin	165 kg/ha^{-1} above-ground parts of plants
Yellow lupin	38 kg N/t^{-1} DM above-ground parts of plants
Field bean	110 kg N/ha^{-1} 151 kg/ha^{-1} 151 kg
Lucerne	21-180 kg N/t^{-1} DM above-ground parts of plants
Clover	18 kg/t^{-1} DM above-ground parts of plants
Red clover	34-41 kg N/t^{-1}DM above-ground parts of plants
Pea	150 kg/ha^{-1} above-ground parts of plants
Field pea	35 kg N/t^{-1} DM above-ground parts of plants
Ornithopus	37 kg N/t^{-1} DM above-ground parts of plants
Soybean	175 kg/ha^{-1} above-ground parts of plants 36 kg/t^{-1} DM above-ground parts of plants
Lentil	109-136 kg N/ha^{-1}
Bean	65 kg/ha^{-1} above-ground parts of plants

The amount of nitrogen associated with rhizobia allows for a significant reduction in the use of mineral fertilisers. The nitrogen used is not used by crops, and about 25% is leached during the vegetation period, which has an impact on the condition of the soil and the environment. The use of high doses of these fertilisers is associated with water pollution (eutrophication), biodiversity reduction, salinisation of soils, greenhouse gas emissions (N_2O) and increased costs. Reducing the use of nitrogen fertilisers brings economic and, above all, environmental benefits. The use of naturally occurring cycles and processes in nature is conducive to environmental protection and can support agricultural activities.

The benefits of biological nitrogen fixation to agriculture are the following:

- the integrated cultivation of legumes is conducive to the development of resilient cultivation systems,
- increased availability of nitrogen for crops grown as a result,
- lower consumption of mineral fertilizers,
- reduction in carbon footprint,
- support for sustainable agriculture,
- stabilisation of food production over time,
- the cultivation of legumes has a positive effect on the yields of crops grown in rotation and on the nitrogen content of grains and seeds,
- has a positive effect on soil quality,
- increases plant and microbial biodiversity,
- combats pollution of waters and eutrophication,
- reduces NO_2 emissions to the atmosphere.

The process of fixing atmospheric nitrogen is influenced by many factors, including: extreme temperatures, soil reaction, salinity, toxic chemicals, mineral fertilisers, fungicides, antibiotics and heavy metals (Paśmionka 2017). These factors can affect the survival of rhizobia, their growth and ability to enter into symbiosis with legumes. In addition, some factors influence the process of creating plant-bacterium symbiosis itself or its effectiveness. The high level of nitrogen in the soil inhibits the formation of papilla and the binding of atmospheric nitrogen. Salinisation of the soil can inhibit nitrogenase activity and consequently weaken the nitrogen fixation process. A soil reaction (pH below 4.8) may also reduce bacterial survival, papilla formation, nitrogenase activity, and weaken the attachment of rhizobia to root hairs. The procedure of using bacterial vaccines should be carried out very carefully, because improperly performed inoculation or too few bacteria in the preparation will weaken the process of establishing cooperation.

3.4. Soil cultivation

Soil cultivation before the sowing of lentils is similar to that of other spring varieties. After harvesting the pre-harvest, you need to thoroughly weed the field, because the lentils are characterised by very slow initial growth and weeds strongly compete for water and nutrients, weaken its growth and development, affect the reduction of yield. Therefore, shallow tillage or cultivating (rigid-tine cultivator - stubble cultivator) and multiple harrowing that destroys emerging weeds (if catch crops are not sown) should be carried out. In late autumn the ploughing must be carried out at medium depth (around 25 cm). You can use a reversible or pendulum plough, which reduces the cost of the procedure, but above all limits the compaction of soil on headlands with the wheels of the tractor.

Spring field work for lentils should be started as early as possible, because their aim is to reduce water losses as much as possible and to create the most favourable conditions for placing seeds at the right depth. This promotes rapid and balanced emergence and deep rooting of plants, which reduces the sensitivity of plants to periodic droughts. Immediately before sowing, the soil should be seasoned, preferably with a cultivation set that crushes the lumps, levels and loosens the role to the depth of seed sowing. If we sow with a cultivation and sowing unit, then it is possible to sow lentils immediately after the spring levelling of the field with a harrow, or even without this treatment. All growing treatments must be carried out with appropriate soil moisture so as not to cause excessive spraying or crushing. Due to the flaccid stalk, lentils often lie down, which is why it is very important to carefully level the surface, because this allows low setting of cutting units of lentil harvesting machines.

3.5. Fertilisation

Lentils need 37-49 kg of nitrogen, 2.94-7.25 kg of phosphorus and 2.4-23.7 kg of potassium to produce one tonne of seeds. Fertilisation with phosphorus and potassium enables normal growth and development of lentils and the binding of free nitrogen by rhizobia. The level of fertilisation with these components should be determined as in the case of other crop species, primarily depending on the expected yield and soil abundance of these components (Tables 3, 4).

Thanks to the ability of the rhizobia *Rhizobium leguminosarum* to fix nitrogen, lentils do not need to be fertilised with this component, its small amounts (15-25 (kg/N ha^{-1}), should be applied immediately before sowing. On fertile soils and after fertilised pre-harvests, a large dose of nitrogen, and especially in well-moistened sites, this treatment can be omitted. Lentils respond positively to micronutrient fertilisation, the use of which is intentional in positions with a low content of boron and molybdenum. They can be applied to the soil in solid form (boron – boron superphosphate or borax, molybdenum – sodium or ammonium molybdate) and in the form of foliar feeding. This treatment is most often performed at the beginning of lentil budding in doses of 0.04 molybdenum (Mo) and 0.2 kg/ha^{-1} boron (B). These elements influence root weight growth, seed and grass yields.

Table 3. Phosphorus doses (P_2O_5 in (kg/ha^{-1}))

Soil complex	Sulphur content in soil				
	b. low	**low**	**medium**	**high**	**b. high**
Defective wheat (3)	50	30	15	0	0
Very good rye(4)	50	30	15	0	0
Good rye	55	35	20	15	15
Mountain wheat	55	35	20	15	-

Table 4. Potassium doses (K_2O in (kg/ha-1))

Soil complex	Sulphur content in soil				
	b. low	**low**	**medium**	**high**	**b. high**
Defective wheat (3)	75	60	45	40	0
Very good rye(4)	75	60	45	40	0
Good rye	75	75	60	50	20
Mountain wheat	90	75	55	45	0

Soil pH most favourable for lentils is between 6.0 and 6.5. In the case of lentil cultivation on acidic soil, liming may be carried out immediately after the pre-harvest harvest or earlier, under other species in rotation (Table 5). There is a high concentration of aluminium ions on acidic soils, which can inhibit root growth and cause poor development of rhizobia. On soils with low magnesium content (less than 2-3 mg/100 g – lighter soils and 3-5 mg/100 g heavier soils), at least one third of the lime doses should be applied in the form of magnesium lime. Magnesium fertilisers should be sown at a dose of 60-80 kg/ha-1 in locations with appropriate soil pH but showing magnesium deficiency.

Table 5. Calcium doses (CaO in (t/ha^{-1}))

Soil complex	Liming requirements		
	necessary	**needed**	**recommended**
Very good wheat			
Very good rye	4.5	3.5	2.5
Mountain wheat			
Good wheat	3.5	2.5	1.5
Strong cereal-fodder			
Good rye	2.5	1.5	1.0

3.6. Sowing

For sowing lentils, use healthy, undamaged seeds with a high germination capacity. The date of sowing should be as early as possible, as in the case of other legume species (third decade of March until the second decade of April). Delaying sowing by 12-14 days may result in a reduction in seed yields of up to 25-30 %. The standard for sowing lentils should be 200 seeds per 1 m2 for large-seeded forms and up to 250 for small-seeded forms. Depending on the size of the seeds, the sowing rate may range from 60 to as much as 120 kg/ha-1. Due to the hypogeal way of germination, the seeds require a deeper covering with soil, i.e. 4-6 cm, this has a beneficial effect on seed germination and the development of the root system. Row spacing, which guarantees optimal plant growth and development, should be between 15 and 20 cm.

The recommendations for the preparation of lentils for sowing are in line with the guidelines for other species of legumes. Treatment with a bacterial vaccine is a cheap procedure and, as a rule, has a very beneficial effect on yielding. In addition, when the break in the cultivation of lentils in a given field was longer than 4-5 years, the seeds should also be treated with such a bacterial vaccine. For the envisaged use of the bacterial vaccine, the seeds should be treated with seed treatment approximately 2 weeks before sowing and immediately before sowing with a bacterial vaccine.

It is advisable to use one of the following seed treatments against fungal diseases.

A twisted test of the seedling shall be carried out prior to sowing. The amount of sowing shall be calculated on a case-by-case basis, taking into account the actual quality characteristics of the seeds using the formula:

sowing (kg/ha) = a x b/c;

where: a – planned planting density

b – weight of 1 000 seeds,

c – useful value of seeds (purity x germination capacity)

It is also recommended to leave crossing paths for spraying aggregates used for the maintenance of plantations. If a strong rain falls after sowing and a shell forms, light harrows can be used, but in this case it is better to use a light crushing shaft. Seed drills, coarse seed drills or groove seed drills with top seeding shall be used for seed sowing. Depending on the type of the seed drill, mechanic or hydraulic coulter pressure should be used to place the seeds at the same depth.

4. CULTIVATION

4.1. Directions for cultivation

The edible lentil is an annual self-pollinating and diploid species (2n=2x=14) with a genome size of 3 759 Mbp. Extrapollination occurs sporadically in 1-6% of the flowers. Therefore, in order to obtain new varieties of this species, it is possible to use both breeding methods dedicated to self-pollinating and allogamous plants. Edible lentil cultivation and breeding of new varieties is mainly concentrated in Canada, Australia and India. Currently, its global production is 6.33 million tonnes of seeds, obtained from an area of 6.10 million hectares, and the largest producers are Canada, India, Turkey and the USA. World yields of lentil seeds range from 0.5 to 2.8 tonnes per hectare, depending on the agro-ecological conditions, the variety grown and the agrotechnology used. The main factor limiting the popularity of lentils is the instability of their yield. Satisfying the world’s needs for edible lentils is possible by cultivating varieties with high yield potential, increasing the crop area and continuously improving genotypes to adapt them to local habitat conditions and ongoing climate change.

The main rearing directions for the edible lentils are as follows:

- growing varieties with high yield potential, adapted to different agroclimatic conditions;
- increasing the protein content of seeds while reducing cooking time;
- an increase in the weight of 1 000 seeds;
- shortening the vegetation period of plants;
- increased resistance to diseases such as field bean rust, fusarium wilting and root rot, caused by *Uromyces viciae-fabae* (Pers.), respectively J. Schrot., *Fusarium oxysporum* Schl., *Fusarium solani* (Mart.) Sacc.));
- increasing resistance to pests (pea aphid *Atythesiphon pisum* Harris, European corn

borer moth *Ostrinia nubilalis* Hübner);

- Increased tolerance to drought and soil salinity.

The edible lentils are a predominantly self-pollinating species with a very low cross-breeding rate. Therefore, classical lentil breeding methods are similar to other self-pollinating plants and are based on cross-breeding and subsequent selection, using various techniques, including molecular ones. The main purpose of cross-breeding is to increase the degree of genetic variability. Choosing the right parents plays a key role in the success of cross-breeding, which is a difficult procedure and its effectiveness is only 10-50%, because small and delicate flowers are susceptible to damage during castration and pollination. The favourable cross-breeding results also depend on the genotypes involved and the prevailing climatic conditions (air temperature and humidity, insolation). Successful cross-breeding is facilitated by an adequate size of flower buds. Special care should be taken during castration and pollination to minimise mechanical damage to the floral parts. The time of pollination and fertilisation are the key factors determining the success of cross-breeding. Cross-breeding between species within the lentil genus (*Lens*) shows the existence of significant barriers both between species and within the species itself. Preliminary research indicates that in the future, obstacles to cross-breeding between species can be overcome using the technique of progenitor fusion.

Long-term recombinant breeding has significantly narrowed the genetic variability of edible lentils (Sadras et al. 2021). Mutations are an additional source of variability, covering all types of hereditary genetic changes in the body. Cultivation techniques based on induced mutations are used to enlarge the genetic base and reproduce the genetic variability of lentils. The success of mutation culture depends on the effectiveness of induced mutations, the desired frequency and spectrum of mutations (Prasad et al. 2016). The advantage of this method is to shorten the breeding time of improved varieties, and the process changes only a small part, not the entire genome. Lentil mutation breeding involves careful selection of mutants with altered morphological architecture and focuses on finding elite breeding lines in terms of yield and yield characteristics. It is believed that induced mutagenesis is the best solution in lentil breeding, allowing for the expansion of the genetic base and the creation of new useful mutants for agricultural practice. Some studies to date have confirmed the effectiveness of chemical mutagenesis in the breeding of new lentil varieties. The combined application of physical and chemical mutagens has also made it possible to improve the yield-forming characteristics and yield levels of other species of legumes.

The use of *in vitro* breeding techniques can be an effective tool to manage genetic variability and accelerate the conventional cultivation of legumes (Kumar et al. 2022). One of the necessary conditions for the success of genetic transformation using *in vitro* culture is a reliable regeneration protocol. Compared to the success achieved for other species of legumes, this technique was initially difficult to apply to edible lentils due to their resistance. These techniques have gradually improved over the last few decades. A rapid, effective and reproducible *in vitro* lentil shoot regeneration protocol was obtained by using different explants and concentrations of BAP and BA (6-benzylaminopurine and 6-benzyladenine). Successful regeneration of lentils stems *in vitro* was achieved through a small modification in Murashage and Skoog (MS) medium. To a large extent, higher levels of BAP and BA facilitated the regeneration of shoots with lentil genotypes. In the case of edible lentils, induction of flowering in vitro was demonstrated, followed by the establishment of pods and the formation of seeds directly from shoots regenerated in vitro, which is extremely important in terms of improving and shortening the reproduction process of this species.

In the cultivation of new varieties of lentils, it is also possible to select starting materials with markers. Emergence of PCR-based markers *Polymerase Chain Reaction*) extended lentil genetic map research. The first genomic library was constructed using the ILL5588 lentil variety. Currently DNA chip-based markers using single nucleotide polymorphisms (SNP) are gaining popularity compared to PCR-based markers in Next Generation Sequencing (NGS). Thanks to the next generation DNA sequencing, various studies have also described some genome areas, a genome map and QTL (Quantitative Trait Loci). Currently, there is a rapid development of various types of breeding methods, helpful in creating new varieties of edible lentils. The ultimate goal of breeding is to obtain high-yielding varieties of lentils, resistant to various types of stress (abiotic, biotic) and with high adaptation to a variety of agroecological conditions (climate, soil, agronomics).

5. INTEGRATED PROTECTION AGAINST PESTS

5.1. Reducing the occurrence of weeds

Lentil plants are very sensitive to the competitive influence of various weed species, in particular for up to four weeks from the time of emergence. This is mainly due to the biology of lentils (slow growth in the first four weeks after emergence). Depending on the region of Poland where the lentil plantation is located, the type of soil, pre-harvest, and especially weather conditions, the sowing of this extremely valuable species is threatened by several to even a dozen species of weeds. Some of them (e.g. field violet or chickweed) are not very competitive with lentil plants, but several other dicotyledonous (especially perennial) and monocotyledonous species can be a big threat to lentil plantations if they are not effectively removed from the field at the right time. Currently, the assumptions regarding integrated crop protection against weeds focus mainly on reducing weeds, through directional and precise control of protection using various methods (non-chemical and chemical), in order to reduce their abundance as much as possible, so that they do not pose a threat to the crop (Dobrzański 2009, Dobrzański and Adamczewski 2009).

5.1.1. The most important weed species

The most important annual monocotyledonous species found in lentils include one-sided weed and trichinella, and from dicotyledonous species - , white footgoose, field pansies, cling hugs and so-called chamomile weeds (e.g. scentless mayweed). Sometimes the problem (most often local resulting mainly from defective agrotechnology) may be long-term taxons, i.e. dog grass, field horsetail or field thistle (Paradowski 2013, Paradowski and Czubiński 2018).

Barnyard grass is an annual spring, thermophilic species, belonging to the *Poaceae* family, reaching a height of up to 90 cm (30-60 cm on average) (Figure 2). The period of its intense emergence occurs in the spring to the beginning of summer (from May to July). It blooms from July to September, producing between 200 and 1 000 caryopses, whose viability in the soil ranges from three to seven years. This species is considered to be the common weed of most cultivated species, spring thermophilic plants. It germinates massively when the soil warms up to a temperature of about 10-15 °C. Barnyard gras is an indicator species of warm, rapidly heating and nitrogen-rich soils, which it takes in very large quantities. The economic damage threshold of this species has not been defined for lentils; however, it is assumed to be 3-6 plants per 1 m2.

Figure 2. Barnyard grass (***Echinochloa crus-galli***)

Yellow foxtail is an annual, spring, thermophilic species belonging to the *Poaceae* family, growing to a height of up to 130 cm (10-50 cm on average) (Figure 3). Intense emergence occurs in late spring to autumn (June to September). Flowering from July to September, it produces between 400 and 800 caryopses whose viability in the soil is between 10 and 15 years. This species is considered problematic for most cultivated thermophilic spring crops. In addition, it occurs in large quantities on stubble fields, fallow lands and set-aside land. Seeds germinate when the soil warms up to a temperature of about 15-20 °C. Yellow foxtail is an indicator species of dry, very warm, quickly warming soils. The economic damage threshold of this species has not been determined for lentils, but in most crops it is six plants per 1 m2.

Figure 3. Yellow foxtail *Setaria pumila*

Couch grass is a perennial species belonging to the *Poaceae* family. It reaches a height of up to 200 cm (30-150 cm on average) (Figure 4). The emergence period falls in autumn (September-November) and spring (March-May). It flowers from June to September, producing from 100 to 500 grains whose lifespan in the soil is between four and ten years. It can reproduce in two ways: generatively (through seeds) and vegetatively (through underground stolons-rhizomes). It is a very common species, found on all types of soils, except peat soils. It infests practically all agricultural and horticultural crops and is common on fallow and set-aside land. Couch grass rhizomes can survive flooding lasting 30-45 days and frost reaching -40 °C. A single plant can produce 140 m of runners and 200 above-ground shoots. Very expansive species, characterised by high competitiveness for all crops. The economic damage threshold for this species for most cultivated plant species is assumed to be 10-15 units per 1 m2. Couch grass is a hypercumulative macroelement because it can draw 100-120 kg of nitrogen, 50-70 kg of potassium and 20-30 kg of phosphorus from fields. In addition, couch grass releases into the soil allelochemical compounds (negative allelopathy phenomenon), which have an adverse effect on the growth and development of other plants in which these substances interfere with the uptake of macronutrients, i.e. nitrogen and potassium. In addition, it is an active 'participant' in what is known as the 'green bridge'. This phenomenon involves the transmission of certain pests (e.g. aphids, violins, plotters) or diseases (e.g. powdery mildew) by plants (as a vector).

Figure 4. Couch grass (***Elymus repens*** (syn. *Agropyron repens)*

The white goosefoot is an annual species, the spring quinoa, belonging to the *Amaranthaceae* family reaching a height of up to 150 cm (10-100 cm) (Figure 5). Seeds germinate intensively in spring, early summer and autumn (April-October). Flowering occurs from June to October, producing between 200 and up to 20 000 seeds, whose viability in the soil ranges from 10 and 15 years (and even up to 60 years). It is a very common weed that inhabits various types of soils, especially those rich in nitrogen and potassium. It infests all agricultural and horticultural crops. Due to the high productivity of seeds, which retain their germination capacity for a long time, it is a very dangerous weed of agricultural fields. In addition, it releases into the soil allele compounds (negative allelopathy), which negatively affect the growth and development of certain agricultural plants. It is characterised by high competitiveness for all cultivated plant species. It is a hyperaccumulator of macronutrients, i.e. nitrogen and potassium. The economic damage threshold of this species has not been established for lentils, but it is assumed that as little as 2 pieces per 1 m2 pose a threat to lentil plants.

Figure 5. White footgoose *Chenopodium album*

Field pansy is an annual, spring and winter species, belonging to the family of violets (*Violaceae*), growing up to 50 cm high (average 5-35 cm); (Figure 6). Seeds rise in spring and autumn (March-May to September-November). It blooms from April to November, producing from 150 to 3 000 seeds, the lifespan of which in the soil is from 2 to 10 years. It is a very common weed found on different types of soils. It fills all field crops, and it also appears on fallow and untilled soil. This species is highly competitive in the initial period of crop development and over-densifies the field, worsening phytosanitary conditions. Field pansy may be a vector for certain fungal diseases, e.g. powdery mildew, downy mildew or fine leaf spot. The economic damage threshold of this weed has not been determined for lentils, but for most crops it is 20-25 plants per 1 m2.

Figure 6. Field pansy *Viola arvensis*

Scentless mayweed is an annual, spring and winter species, sometimes biennial, belonging to the *Asteraceae* family it grows up to 80 cm in height (15-60 cm on average) (Figure 7). Seeds rise in spring and autumn (March-May to September-October). It blooms from May to October, produces from 5 000 to 300 000 seeds, the lifespan of which in the soil can be from 6 to 10 years. It occurs commonly, especially on sandy and loamy soils, and especially humus and nutrient-rich soils with low calcium content. It is found in the crops of most agricultural plant species. Moreover, it is a highly competitive species. The economic damage threshold has not been defined for lentils, but in most agricultural crops it is between two and five plants per 1 m^2. At high intensity, it strongly shades the crop, causing it to lie down. Sometimes it may even cause a crushing of the cultivated plant. In addition, it very often causes difficulties during harvesting.

Figure 7. Scentless mayweed *Tripleurospermum inodorum*
(syn. *Matricaria maritima inodora, M. perforata*)

Chickweed is an annual species, spring and winter, sometimes biannual, evergreen, belonging to the carnation family (*Caryophyllaceae*), reaches a height of between 60 and 90 cm (10-30 cm on average) (Figure 8). The emergence period can take place theoretically throughout the year, but practically it rises from February to November. It also blooms almost all year round, with the exception of a period of severe winter frosts, most often, however, from April to October, producing from 1 000 to 25 000 seeds, the lifespan of which in the soil can range from 5 to 70 years. It can reproduce in two ways: generatively (seeds) and vegetatively (from part of the stem in the shoot nodes producing newcomer roots). It is present on soils that are rich in macro-elements, mainly weeding croplands, and may also occur in vegetables and on fallows or untilled land. On soils intensively fertilised with macronutrients, it grows very strongly, depleting the soil of nutrients (mainly nitrogen). An important characteristic of chickweed seeds is the possibility to germinate at a temperature of 1–2 °C. This species can produce between 2 and 5 generations within a year. The economic damage threshold of this species for lentils has not been defined, but it is assumed that 40-60 plants per 1 m2 may constitute a significant competition for lentil plants.

Figure 8. Chickweed – *Stellaria media*

Goosegrass is an annual species, spring and winter, belonging to the bedstraw family (*Rubiaceae*), whose stem can reach 200 cm high (average 30-150 cm) (Figure 9). Seeds rise in autumn (September-November) and spring (March-May). It blooms from May to October, producing from 100 to 500 splits, the lifespan of which in the soil can be from 5 to 10 years. It is a very common and cumbersome weed, occurring mainly on nitrogen-rich soils with a slightly acidic to neutral reaction. It covers in weed mostly agricultural crops, sometimes horticultural. The presence of bedstraws in the field promotes lodging and makes harvesting difficult. The seeds of this species of weeds contaminate the seeds for sowing the edible lentils. This species is very competitive, extremely nitrophilic. Its rigid and hooked hairs cause it to ‘stick’ to other plants, creating dense ‘scrub’ that is difficult to remove. With a very high intensity (more than 100 plants per 1 m2), this species can completely crush the arable crop. The economic damage threshold for lentils has not been determined, but it is assumed that already 1-5 plants per 1 m2 can significantly reduce yield and cause difficulties during lentil harvesting.

Figure 9. Goosegrass (*Galium aparine*)

Field thistle is a perennial species, sometimes it can be two years old, belongs to the *Asteraceae* family it grows to 180 cm in height (40-150 cm on average) (Figure 10). Seeds rise in autumn (September-October) and spring (March-May). Flowers from July to October, producing between 3 000 and 40 000 seeds, which can have a lifespan in soil of between 5 and 20 years. Like many other weed species, it can reproduce in two ways, generatively (seeds – mainly in spring) and vegetatively (from root to root, throughout the growing season). Field thistle is a very onerous weed that occurs in crops of all crop species, as well as on grassland and stubble. It grows on all types of soils and thrives best on airy soils, rich in nutrients, and absorbs nitrogen, potassium and calcium most intensively. It has a very high degree of competitiveness vis-à-vis the cultivated plant. The economic damage threshold in most agricultural crops ranges from 0.5 to 1-2 plants per 1 m2. At a high level, it can crush the arable crop, and also makes it difficult to harvest the lentils mechanically.

Figure 10. Field thistle *Cirsium arvense*

Horsetail is a perennial species belonging to the horsetail family (*Equisetaceae*), it can reach up to 40 cm in height (15-30 cm on average) (Figure 11). The seeds sprout in the spring (March-April) and flowering (breeding) takes place from March to April sometimes until May, during which the horsetail produces huge amounts of spores distributed by the wind. This species can reproduce in two ways, generatively (via spores carried by the wind, only in spring) and vegetatively (using rhizome tubers and underground rhizomes, throughout the period of its vegetation). It can be found on all soil types, especially at moist sites, with a slightly acidic or acidic reading. It is common in the crops of all agricultural and horticultural species, as well as in fallow and untilled land. It is a weed with a very high competitive force, and at the same time extremely difficult to destroy (mechanically, chemically). The economic damage threshold for this species has not been clearly defined, but it is assumed that already 5-8 units per 1 m² could represent significant competition for lentil plants. When present at a large, so-called ‘placeholder’, it can have a very strong competitive impact, even by jamming the arable crop.

Figure 11. Field horsetail (*Equisetum arvense*)

5.1.2. Non-chemical methods for regulating weed

Preventive measures are very important in the non-chemical reduction of weed infestation of lentil plantations. The selection of a suitable cultivation site (in good agricultural condition) and use of good quality seeds are important. Proper crop rotation and well and carefully made soil cultivation, as well as the use of appropriate mechanical treatments (e.g. care) are important (Dobrzański and Adamczewski 2009, Zbytek 2009).

Limiting the weeding of the lentils with mechanical treatments occurs already during the preparation of the planting site and after its emergence. Weeding with perennial weeds should be reduced before sowing. After the risings, harrowing can be carried out when the lentil plants reach a height of about 6-7 cm. The treatment shall be performed perpendicular to the direction of sowing, preferably in the afternoon.

5.1.3. Chemical methods of weed infestation control

The range of herbicide active substances recommended to protect lentil plantations from weeds is limited, but it is increasing from year to year.

Before rising, it is possible to effectively control both monocotyledonous and dicotyledonous weeds (the condition is properly moist soil!).

On the other hand, only graminicides, i.e. herbicides, which only control uniform weeds, can be used in the post-emergence (or foliar) period.

The list of plant protection products allowed in Poland is published in the register of plant protection products. Information on the scope of application is given on the labels. A repository of plant protection products can help to choose a pesticide (https://www.gov.pl/web/rolnictwo/wyszukiwarka-srodkow-ochrony-roslin). Current information on plant protection products use is available on the Ministry of Agriculture and Rural Development website at: https://www.gov.pl/web/rolnictwo/ochrona-roslin.

The list of plant protection products authorised for IP is available in the Pest Warning System at: https://www.agrofagi.com.pl/133,wykaz-srodkow-ochrony-roslin-do-integrowanej-produkcji-w-uprawach-rolniczych.

5.2. Reduction of fungal diseases

5.2.1. The most important diseases occurring on lentil plants

Lentils, like other species of cultivated plants, are exposed to infestation by the perpetrators of diseases. However, due to its small catchment area, the risk posed by many pathogenic fungi and other disease perpetrators is low. Depending on the area of cultivation, the weather during the growing season and the development phase of the lentils, the following diseases have been observed: seedling blight by *Pythium* sp., *Rhizoctonia* sp., *Fusarium* spp., *Alternaria alternata* and *Cloadosporium* and *Phoma pinodella*. The shoots may be infected with perpetrators of scleroderma rot - *Sclerotinia sclerotiorum*, grey mould - *Botrytis cinerea* and fusarial wilting of the lentils - *Fusarium* spp. Ascochytosis of the lentil (*Ascochyta lentis*) may appear on the leaves. After the pods have formed, if the above fungi are present, they can inhabit the lentil seeds. Species belonging to the genera *Alternaria*, *Cladosporium*, *Botrytis* and *Fusarium* are the most likely to be transmitted by seeds. The importance of diseases in lentil cultivation is presented in Table 6, and Table 7 - diagnostic features of these diseases (Kirk et al. 2008, Kryczyński and Weber 2010, 2011, Nyvall 1989).

Viral diseases may also occur on lentil plants. These are often diseases caused by viruses known and described in crops of other species, e.g. lupins, peas. Some bacteria can also be found on this species.

Table 6. Economic importance of selected diseases and their perpetrators in the cultivation of lentils

Disease	**Pathogen(s)**	**Importance**
Seedling blight	*Pythium* sp., *Rhizoctonia* sp., *Fusarium* sp., *Alternaria* sp., *Cladosporium* sp., *Phoma sp.*	+ +
Fungal rot	*Sclerotinia sclerotiorum*	+
Grey mould	*Botrytis cinerea*	+
Fusarian wilting lentils	*Fusarium* spp.	++
Leaf Asochytosis lentils	*Ascochyta lentis*	++

\+ - low importance ++ - higher importance

Table 7. Diagnostic characteristics of selected lentil diseases

Disease	**Diagnostic features**
Seedling blight	After the lentils rise, already in the cotyledon phase and the initial development of the leaves, the plants have stunted growth, turn yellow and wither, and 2-3 weeks after the rise they die off completely, the roots
Fusarian wilting lentils	Plants in the early flowering phase to the stage of producing pods lose turgor and wither. Infested plants have blackened or brown roots and the base of the stem. The disease is exacerbated when in the flowering phase, the setting of pods in the soil, there is a shortage of water. Plants turn yellow, dry up and do not produce seeds in pods.
Fungal rot	On the stems appear white or grey spots, which form the mycelium of the perpetrator of the disease. The spots are oval and quickly surround the entire circumference of the stem. The shoot dries over time and the plant grows faster and ends its growth. The infested stem is white, with black spores of the perpetrator of the disease visible on its surface.

Grey mould	A grey, loose mycelium coating with the stems of the disease causative organism is formed on the root collar and stem. Mycelium may also be present on leaves and pods. The plant withers and dies after several days from the control of the plant by the fungus.
Leaf Asochytosis lentils	Brown and later russet spots appear on the leaves, on which dark points (fruits of the fungus) may be visible. After some time, the oval spots merge and extensive necroses form on the surface of the leaves. Sick leaves quickly die off.

5.2.2. Non-chemical methods of protection

In the reduction of disease perpetrators in integrated production and protection, all non-chemical methods are used in the first instance. In justified cases where these methods prove to be insufficiently effective, chemical control of pathogens shall be used. The use of non-chemical methods is of a preventive nature. In the cultivation of lentils, they should be used in the fight against plant pathogens, and the grower can use the breeding, biological and agrotechnical method (Mrówczyński 2013).

5.2.2.1. Cultivation method

The resistance of lentils to infestation by pathogens is poorly understood. By observing the plantation, it is possible to assess whether the cultivated lentils are resistant to occurring fungi during the vegetation of this species. Attention should be paid to the entries in the characteristics of the lentil variety that is grown. If plants show increased resistance or tolerance to infestation by e.g. fungi causing seedling blight, fusariosis, or sclerotia, then this variety should be grown.

5.2.2.2. Agronomic method

The agronomic method can reduce lentils infestation by many pathogens mainly through such soil preparation to ensure the optimal conditions for the emergence of lentil seeds. Rapid emergence and nutrient availability increases plant resistance to infestation by soil and airborne pathogens. The following elements of agronomy are important:

- appropriate crop rotation and site selection,
- correct preparation of the soil for sowing (autumn ploughing of crop residues);
- compliance with the rules of appropriate fertilisation, timing and density of sowing.

5.2.3. Chemical protection method

One of the objectives of the introduction of integrated production and plant protection is to ensure the safety of consumers of agricultural products. The use of chemical plant protection products should seek to minimise the risk to organisms present in agrocenosis. Consequently, products classified as toxic to humans may not be used in integrated production. Fungicides should be used in accordance with the current list of products recommended for lentil cultivation in integrated production (IP).

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

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

5.3. Reducing the occurrence of pests

5.3.1. Most important pests occurring on lentils

Lentils are not particularly susceptible to pests, mainly due to their small cropping area. Legumes can be damaged by many species of pests, but in the case of lentils, they rarely cause losses of economic importance. However, many species of pests may appear on lentil plantations (Hołubowicz-Kliza et al. 2018, Tratwal et al. 2018) (Table 8).

Table 8. The most important species of lentil pests

Pest	Importance
Lygus bugs (*Lygus* spp.)	(++)
Lucerne bug (Adelphocoris*lineolatus* Goeze)	(++)
Snout beetle (*Sitona* spp., *Charagmus* spp.)	(++)
Turnip moth (*Agrotis* spp.), grub (Scalabeidae)	(++)
Thrips (Thysanoptera)	(+)
Whitefly (Aleyrodidae)	(+)
Aphids (Aphididae)	(+)
Leafhoppers (Cicadellidae)	(+)
Pod-shaped beetle (*Laspeyresia nigricana*)	(+)
Red spider mite (*Tetranychus urticae*)	(+)
Mincers (*Phytomyza* spp.)	(+)
Chalcid wasp (*Bruchophagus* spp.)	(+)
Litter (*Delia* spp.)	(+)
Pod worms (*Bruchidius* spp.)	(+)
Nematodes (Nematoda)	(+)
Snails (Molusca)	(+)

(+) – minor importance pest (++) – pest of local importance

Yarn – mainly tabby, clover, damp, grey and multi-eaters. These are beetles of the shrew family, 4-8 mm long. They appear as one of the first pests on the plantations. The most dangerous for legumes are the damage caused by beetles during the spring period on young emerging plants. The greatest losses occur during the seed germination and emergence phase up to the 6 leaf stage, especially under drought and low temperature conditions. In the leaves they bite characteristic teeth (the so-called sinus feed), which reduces the assimilation surface of plants and increases the susceptibility of plants to disease. Older plants are usually less damaged and more resistant to beetle foraging and can compensate for losses as they grow. The larvae damage the root hairs and root nodules in which bacteria fixing free nitrogen from the air develop. Damaged plants are inhibited in growth, which in the final phase causes a decrease in seed yield.

Aphids – mainly beetroot, alfalfa and pea aphids – suck juices from tissues, causing fragments and even whole plants to die off. At the feeding sites and as a result of plant weakening, a secondary infestation by disease pathogens may occur. Aphids can also transmit viruses.

A similar spectrum of harmfulness is characterised by **jumpers, whiteflies and hop spider mites appearing** on crops, especially in rainless and hot years.

Among the pests of lentils, there are also **different-winged bedbugs,** sucking juices from tissues. Moreover, locally, **alterations** and **a lucerne bug** can appear quite plentiful, primarily feeding on leaves, shoots and flowers.

True bugs (both adults and larvae) directly harm the plant by sucking out juices, causing deformation and withering of its fragments, and in extreme cases, the death of entire plants. Weakened plants are more sensitive to adverse climatic and soil conditions, and as a result of mechanical tissue damage – being prone to secondary infestations by pathogenic agents.

With respect to **thrips**, both adults and larvae are harmful as they suck juice from leaf tissues, flower buds and pods. In the case of a high intensity of the pest, small, necrotic spots are visible on the damaged leaves (white on flowers, silvery on young pods); eventually these organs wither and fall, and the pods become stunted.

The butterflies **of pod shaped beetles** pods appear from May to July. The caterpillars feed inside the pods, but they can also feed on leaves and flowers. Higher temperatures and dry, airless weather are conducive to the development of the beetle. Meanwhile, during the seed harvest period, moist conditions cause softening of pods and seeds, which helps caterpillars drill inside and facilitates their further development.

Germinium larvae from the litter family attack the emerging plants. As a result of damage to seeds, cotyledons and growth cones, emerging plants blacken and die, or do not germinate at all. The laying of eggs through the litter is facilitated by the simplifications used in the cultivation.

Local damage can be caused by **nematodes,** which are especially dangerous on humus and moist soils. Invasive larvae winter in the plant material, therefore it is important to carefully remove the crop residue.

Local losses can also be caused by **mini-worms** whose larvae, by feeding on the leaves, limit their assimilation surface and **snails.**

For several years there has been an increase in the risk posed by soil pests, mainly cutworms (caterpillars of mouldy butterflies), drillers and crawfish. When crops are strongly controlled by soil pests, the development of so-called alopecia is observed in the seeding fields. Of particular importance are cutworms, which favour agrotechnical simplification, monoculture and close proximity to legumes, leaving crop residues, no or late winter ploughing and climate warming. Damage caused by soil pests can be a source of secondary fungal or bacterial infections.

A growing legume cultivation area, changes in production technology, widespread use of herbicides, fungicides, foliar fertilisation, and limited crop rotation along with progressing climate warming create conditions conducive to changes in pest development, as well as to the sudden mass appearance of species previously not relevant to the protection of a given plant. The result of pest feeding is not only a reduction in the green weight, but also a reduction in the germination capacity of the seeds and their commercial value. Integrated plant protection and production focuses on prevention measures, allowing intervention as a last resort. Therefore, continuous, systematic observation of the plants and recording of pest outbreaks is required. The most effective is the direct lustration of plants in search of damage or establishment by pests. Complementary methods should also be used, such as yellow dishes or whiteboards in the case of aphids. It is also important to be able to recognise the pest species, know its biology and potential dates of appearance on the plantation (Figure 12).

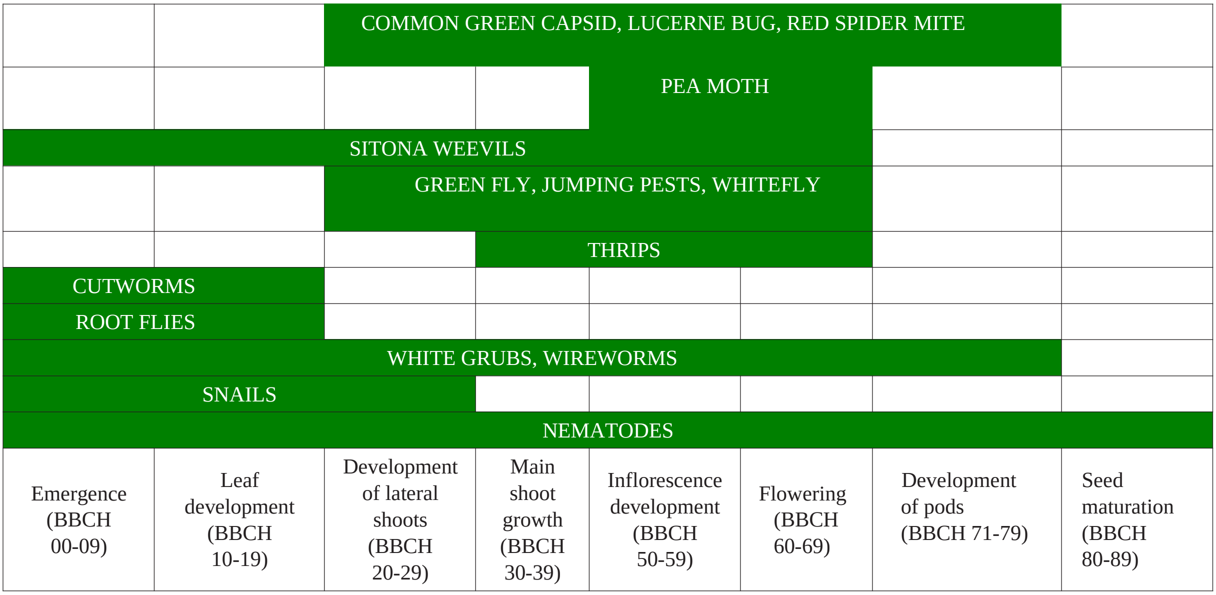


Figure 12. Potential dates for the occurrence of the most important pests during lentil vegetation.

5.3.2. Non-chemical methods of protection

After harvesting, it is important to carry out a set of post-harvest tillage operations aimed at finely crushing plant residues (places of overwintering and development of some pests), limiting the seed bank of weeds, including perennials. In the autumn, it is recommended to make deep tillage, which has a phytosanitary task. A thick layer of soil covers the wintering stages of pests, weed seeds and fungal spores. It also brings to the surface pests that are found deeper, exposing them to adverse weather conditions. Additionally, soil pests are mechanically destroyed.

One of the basic principles of integrated pest management is preventive measures, an important element of which is proper agrotechnology (Pruszyński and Free 2009, Pruszyński et al. 2012, Pruszyński 2016). This is particularly important in the initial growth stages when plants are particularly sensitive to attacks by specific pest species. Properly managed lentil protection should involve a wide range of agrotechnical methods. The increasingly common use of simplified cultivation methods in connection with climate change creates favourable conditions for the development of pests. Proper observance of basic agrotechnological recommendations is a key element of the programme of protecting against pests (Mrówczyński 2013) (Table 9).

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

Pest	**Methods and measures of protection**
Lygus bugs Lucerne bug	proper crop rotation, ploughing, spatial isolation from other legumes, control of weeds, early harvest, low mowing before winter
Thrips	proper crop rotation, early sowing, spatial isolation from other legumes, sustainable fertilisation, weed control, deep autumn ploughing

Pea aphid Leafhoppers Whiteflies	early sowing, balanced fertilisation (mainly N), spatial isolation from other legumes, including perennials
Bean weevils	harvesting as early as possible, deep autumn tillage
Pea moth	proper crop rotation, early sowing as possible, spatial isolation from other legumes, including perennials
Two-spotted spider mite	limiting weeds and plant residues, balanced fertilisation, spatial isolation, mainly from root and fruit crops
Leaf miners	ploughing, sustainable fertilisation, weed control
Wireworms, grubs, cutworms	proper crop rotation, ploughing, discing, weed control, higher seed sowing standard, deep autumn ploughing
Root flies	early sowing, higher seed sowing rate, weed control, accurate manure ploughing
Snails	proper crop rotation, stubble cultivation, disking, early and deeper sowing, weed control, crushing crop residues, deep autumn ploughing
Nematodes	removal of plant residues

In the case of lentils, as in other legume species, the use of proper crop rotation is very important. Many pests overwinter in the top layer of soil or leftover plant residues. For the same reason, it is recommended to use spatial isolation from other legumes (do not grow one after another) and other host plants of individual pests, e.g. perennial legumes in the case of pea aphid or leafhoppers. Spatial isolation also helps make certain pests fly over longer distances. Beneficial organisms living in the agrocenosis, which create the so-called natural environmental resistance, also play an important role in pest control (Boczek and Lipa 1978, Fiedler 2007, Pruszyński 2007, Sosnowska and Fiedler 2013).

Preparing a site for the cultivation of this species, proper fertilisation has a positive effect on the condition of plants, because it is particularly important in the initial stage of plant growth, when they are extremely sensitive to attack from individual species of pests. Appropriate actions to limit potential damage caused by individual species of pests can be taken already at the time of sowing the seeds. Faster initial vegetation of plants makes it possible to get ahead of the period of greatest danger from all pests, especially those that are dangerous for emergence. In addition, faster growth helps choke weeds that can be a food base for some pests. Planting is also important, because too dense sowing makes it easier for pests to spread, while too sparse sowing is conducive to weeding. In addition to competition for water, light and nutrients, weeds are also the food base for some pests, e.g. aphids. The harvest date is also very important: too late and there is a risk of greater losses, especially quality losses, caused by insects that can damage the pods.

5.3.3. Chemical methods of protection

Plant protection products should be used in accordance with the current list of plant protection products for integrated production recommended for lentil cultivation. The list of plant protection products authorised for IP is available in the Pest Warning System at: https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.

Messages given on the Pest Signalling Platform (www.agrofagi.com.pl) can be helpful in the systematic monitoring of pests. Before you apply a plant protection product, you should read its use label, which contains information on the extent of pesticide use on individual crops. The list of plant protection products authorised in Poland is published in the register of plant protection products. The plant protection product search engine (https://www.gov.pl/web/rolnictwo/wyszukiwarka-srodkow-ochrony-roslin---zastosowanie) 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.

5.3.4. Methods for determining abundance and damage thresholds

Monitoring for the presence of pests in a plantation is a very important part of integrated plant protection. Systematic, continuous observation makes it easier to assess the current situation in the field and to react quickly if necessary. Therefore, it is necessary to systematically monitor the occurrence of soil pests, weevils, aphids and pod leafhoppers from the moment of emergence to the beginning of ripening, at least once a week, using appropriate methods. The basic element underpinning a properly set date for pest control is the monitoring of pest flights and number. Monitoring is carried out primarily on the basis of visual inspection or – in the case of soil pests – soil sieving. Other methods are also useful, such as sweep-netting or sticky boards. The basic method of plantation inspection is visual inspection (tour). Depending on the shape of the field, it should include the edge of the plantation and two diagonals. Depending on the pest species, the average number of pests per 1 m2 or 100 randomly selected plants should be checked. Such observations should be carried out in several places on the plantation. Observations of the occurrence of soil pests involve sifting the soil from several places in dug holes measuring 25×25 cm and 30 cm deep. 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 the event of unsatisfactory effectiveness, resistance or prolonged invasions of harmful insects, such a procedure allows for a quick response and, if necessary, the treatment can be repeated (Malinowski 2003, Węgorek et al. 2013). Proper inspection requires knowledge of pest morphology biology. Regardless of the monitoring method used, the results of the observations should be recorded.

Economic damage thresholds should constitute the fundamental basis for rational protection. In the case of lentils, specific damage thresholds are not developed. It is assumed that the chemical treatment should be carried out after the occurrence of pests on more than 5% of the tested plants, because then the loss in yield is significant and has economic significance.

However, for certain species of legume pests, there are general rules and deadlines for their observation (Table 10).

Table 10. Rules for monitoring pests in legumes.

Pest	Principle of observation	Observation date (BBCH development phase)
Sitona weevils	crop inspection for damage – serrated leaf edges	emergence and leaf development (BBCH 10-19)
Aphids	presence of aphid colonies on all vegetative organs	growth and flowering (BBCH 30-69)
Pea moth	observation of the appearance of caterpillars and the damage they cause; pheromone traps	inflorescence and flowering (BBCH 51-65)
Soil pests	inspection of crops for damage to roots, embryos, cotyledons (characteristic bald patches in sowing)	emergence and leaf development (BBCH 09-15)

Bishop bug Lucerne bug	inspection of crops for the occurrence of imago and larvae as well as damage to leaves, flowers and pods	shoot development until pod maturation (BBCH 21-75)

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 extensive knowledge and experience from the farmer, starting from pest identification, through development elements and habitats, to methods of its limitation 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 about modern methods of plant protection have not only an economic dimension, and the non-application of chemical treatments has a positive impact on the state of the environment (Doruchowski and Hołownicki 2009, Dominik and Schönthaler 2012).

One of the tools facilitating the implementation of the principles of integrated plant protection is systems supporting the adoption of decisions in plant protection. These systems are helpful in determining the optimal 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 Internet Pest Monitoring Platform, run by the Institute of Plant Protection - National Research Institute and partner institutions, contains, among others, the results of monitoring individual development stages of pests in selected locations for the purposes of short-term forecasting.(https://www.agrofagi.com.pl/lang.pl).

6. BIOLOGICAL METHODS IN INTEGRATED PLANT PRODUCTION

6.1. Methodology used

Biological methods use beneficial biological factors: viruses, bacteria, fungi, nematodes and entomophages (parasitic and predatory insects) to reduce the population of pests (pests, causes of plant diseases and weeds) in field conditions and under cover. Biological methods in most cases work more slowly than classical chemical protection. This is influenced by environmental conditions, biology and the mechanism of action of the biological agent on the contained pest species. Biological methods may be interventionist in nature, but in most cases they act as a preventative measure, reducing the development of pest species.

There are three main methods of biological pest control:

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

In biological protection, it is important to properly plan treatments, depending on the condition of the plants. Monitoring the occurrence of pests, including historical knowledge from previous growing seasons regarding the phytosanitary condition of crops, allows for appropriate planning of biological protection measures.

Reducing the pest population in lentils cultivation can be carried out using registered biocidal products containing, for example, bacteria of the genus *Bacillus* or fungi of the genus *Beauveria* or *Paecilomyces* in their composition.

When using microorganisms to control pests in lentil cultivation, remember that:

- are sensitive to high temperatures, low humidity and strong sunlight;
- the bacteria are best used when the first caterpillars/larvae of the pest appear, as the younger stages of the pest are more sensitive to insecticidal bacteria;
- In the first stage of action, entomopathogenic fungi require a temperature of about 25°C and high humidity to germinate and get inside the insect;
- the caterpillars of the pest after eating the insecticidal bacteria die only after 24-72 hours, during this period they can feed and look healthy;
- microorganisms are used with self-propelled or tractor field sprayers; such treatments shall be carried out preferably in the evening or early in the morning;
- it is not possible to use chemical plant protection products after using biological products containing microorganisms;
- they are living organisms and have a short shelf life at room temperature, but can be stored in the refrigerator for up to 6 months.

6.2. Rules for the use of biological plant protection products

Biological plant protection products shall be used in accordance with the product label. The provisions contained in the label are the basis for achieving the effectiveness of the product and must be strictly observed. The quality of the biopreparation is the responsibility of the manufacturer, possibly the distributor, but its proper storage after purchase is the responsibility of the farmer. It should be emphasised that biological agents contain living organisms (e.g. fungal spores, bacteria) which are very sensitive to environmental conditions. They have different mechanisms of action and do not eliminate pests like the chemical plant protection products used, but significantly reduce their populations, usually during a longer period of action.

<u>It is important to remember that:</u>

In the environment, biological factors, i.e. elements of the living environment, directly or indirectly affect the life of organisms. An example could be the antagonistic effects of bacteria of the genera *Bacillus* and *Pseudomonas* on the insecticide fungus *Beauveria bassiana*, which should not be combined with each other.

6.3. Conservation biological protection

Biological protection is not only about the use of registered microbiological biopreparations. It is supported by conservation biological protection, which consists in the modification of the agricultural landscape by humans in order to create appropriate conditions for the development of beneficial organisms in the environment (Sosnowska 2018, 2022). Under favourable conditions, macro-organisms acting in the environment can reduce pest populations in lentil cultivation and thus support the action of biological agents.

Ladybugs, netters and hoverflies feed on aphids, reducing the occurrence of this pest. Insecticidal fungi in the soil environment can reduce the number of wintering developmental stages of pests, such as *the fungus Metarhizium* spp. Insecticide fungi often cause epizootic (mass death) colonies of aphids. An important role is played by insecticidal nematodes, which destroy pests in the soil. The action of these biological agents in the environment can be supported by leaving the beds, trees in the field, sowing melliferous plants (buckwheat, guy, borage, and others), sowing the flower strips and maintaining the appropriate agrotechnology. It should be noted that macroorganisms are not subject to registration in Poland.

In reducing the number of lentil pests, it is also important to protect their natural enemies, which can reduce the populations of various pests in the environment. Beneficial organisms in the environment include: predatory ground beetles, rove beetles and ladybirds, parasitic flies (e.g. tachinidae) and sawflies (e.g. aphids and ichneumonidae), predatory flies (e.g. hoverflies and midges), predatory hemiptera and lacewings, and many others that create natural environmental resistance (Tomalak 2008).

Various species of insecticidal fungi, e.g. *Beauveria bassiana*, *B. brongniartii*, *Cordyceps fumosorosea*, *C. farinosa* and *Metarhizium anisopliae*, can act under favourable conditions in the soil environment, reducing, inter alia, the number of shoots. Aphids on leaves can be infected by insecticidal fungi of the *Entomophthoraceae* family. Often, at high temperatures and humidity, they cause epizootics, i.e. mass death of aphid colonies in lentil crops. That is why it is so important to carry out treatments that have a beneficial effect on the growth of biodiversity in the natural environment of arable fields.

In the environment, not only beneficial insects and microorganisms play a role in reducing pest populations. There are other animal species, such as amphibians, birds and mammals. The common toad feeds on a variety of foods, dominated by snails and insects, often harmful ones. One of the insectivorous mammals is the mole. It is a useful animal that feeds on white grubs and other insects found in the soil. The largest representative of insectivorous mammals is the hedgehog, which hunts at night and feeds on insects, snails and other. Birds play a useful role in the environment by destroying pests, for example the great tit feeds on leaf-eating caterpillars and butterflies in spring and summer.

Predatory birds living near plantations are effective in controlling small mammals (rodents, hares). To enable them to observe, resting poles with a height of at least 3 m should be placed along the plantation, in the amount of 1 piece for every 5 ha of plantation.

Activities that support the effectiveness of biological agents in the environment:

- leaving dead furrows, thickets, shrubs and mid-field refuges that support the development of the beneficial insects and micro-organisms that live there;
- forest surroundings are a refuge for beneficial insects and micro-organisms (e.g. insecticidal fungi);
- sowing honey-bearing plants and creating flowering strips in crops;
- the use of organic fertilisers;
- crop rotation;
- cultivation technologies, e.g. cropless cultivation (higher soil moisture contributes to the efficacy of insecticidal fungi);
- the use of selective chemical plant protection products.

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

6.4. 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 (Pruszyński 2008). Integrated plant protection includes ‘protection of beneficial organisms and creating favourable conditions for their occurrence, in particular for pollinators and natural enemies of harmful organisms’.

Due to the obligation to carry out plant protection in accordance with the principles of integrated protection, chemical treatments should take into account the selection of plant protection products that minimise their negative impact on non-target organisms. This applies in particular to pollinating insects and natural enemies of harmful organisms.

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

- rational use of chemical plant protection products and basing decisions on the currently assessed real threat to crops from pests. It is necessary to consider refraining from treatments if the pest outbreak is not numerous and is accompanied by the occurrence of beneficial species. Consideration should also be given to limiting the treatment area to edge or point areas if the pest does not occur throughout the entire plantation. The use of tested mixtures of plant protection products and liquid fertilisers, which reduce entry to the field and mechanical damage to plants, should be recommended;
- protection of beneficial species by avoiding the use of insecticides with a broad spectrum of action and replacing them with selective agents;
- choosing the treatment time to prevent high mortality among beneficial insects;
- based on the results of studies, dose reduction and adjuvant addition;
- constant awareness that protecting natural enemies of pests also protects other beneficial species present in the field;
- leaving balks, mid-field shelters as a habitat for many species of beneficial insects;
- reading carefully the content of the label accompanying each plant protection product and observing the information contained therein.

Other insects are also very efficient pollinators. In order to ensure the development of wild pollinators in agrocenoses and thus increase pollination efficiency, houses for mason bees or mounds for bumble bees or other facilities for pollinating insects should be placed within the growing area at a frequency of at least 1 pc per 5 ha.

7. CORRECT TECHNIQUE FOR APPLYING PLANT PROTECTION PRODUCTS

7.1. Storage of plant protection products

Plant protection products should be stored:

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

b) in a manner ensuring that they:

- are not consumed or intended for animal feeding,
- are inaccessible to children,
- there is no risk of:
  - contamination of surface and groundwater within the meaning of the water law,
  - soil contamination due to leakage or seepage of plant protection products into the soil profile,
  - entering sewerage systems, except for a separate no-return sewerage system equipped with a sealed sewage storage tank or with sewage neutralisation facilities;

The labels of plant protection products approved by the Minister for Agriculture and Rural Development contain information on the principles of safe storage. Plant protection products in accordance with the principles of good practice should be stored in separate rooms (except residential and livestock buildings). These rooms 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.

7.2. Preparation and execution of spraying procedures Requirements for professional users

Persons or the sprayer operator performing treatments using plant protection products must have appropriate qualifications, confirmed by a certificate of completion of training in the use of such products or consultancy on plant protection products and integrated crop production or another document certifying the acquired authorisation to perform 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. At each stage of handling plant protection products, appropriate work organisation and available technical means should be used, in accordance with the principles of **good plant protection practice**.

Apparatus and equipment for protective treatments

A sprayer or other equipment used to protect crops must be technically efficient, function reliably and ensure 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 a test report and a control mark issued by authorised entities (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. Before performing the procedure, it is necessary to check the technical condition of the sprayer, in particular the condition of: filters, pumps, lubrication and lubrication points, nozzles, field beam, measuring and control devices, liquid system and agitator. It is also advisable to carry out a preventive rinse of the sprayer to remove mechanical debris and any residues of previous treatments from the system.

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

Calibration (adjustment) of the sprayer

Periodic adjustment of the sprayer makes it possible to choose the optimal parameters of the treatment. In accordance with good plant protection practice in the adjustment (calibration) process of the sprayer, the type and dimension of the sprayers and the working pressure should be determined, which ensure the application of the assumed dose of liquid per hectare for the specified operating speed of the sprayer. The adjustment of the sprayer's operating parameters should be performed when changing the type of chemical agent (especially from herbicide to fungicide or insecticide), the dose of the spray liquid, as well as the setting of operating parameters (working pressure, field beam height). The adjustment of the sprayer is carried out each time when replacing important equipment and components of the sprayer (sprayers, pressure gauge, control device, repair of essential elements of the liquid system), as well as when changing the tractor or tyres in the drive wheels. The discharge of the liquid from the nozzles at the specified operating pressure should be checked regularly. When adjusting the sprayer, attention should be paid to the flow capacity of the nozzles and the uniformity (type and size) of the nozzles mounted on the field beam. An example procedure for calibration of the sprayer is contained in the Code of Good Practice for Plant Protection or other thematic studies in this area.

Choice of plant protection product and dosage

In line with the requirements of integrated pest management, selective measures with low risk to pollinators and beneficial organisms should be chosen. Treatments with plant protection products should be planned in a way that ensures acceptable efficacy with the minimum quantity of plant protection product necessary, taking into account local conditions. The dose of the plant protection product should be selected according to the manufacturer's recommendation on the basis of the label, also taking into account the development phase of the plants, their condition and climatic and soil conditions: wind, temperature and humidity of soil and air, type of soil, as well as the content of organic matter in the soil.

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

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

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

Selection of spray liquid volume

In integrated production, the volume of working liquid (l·ha-1) should be selected based on available catalogues, training materials and guides or other thematic studies. When selecting the volume of the working liquid, the following factors should be taken into account: the type of crop being sprayed, the plant development stage, the plant population, the possibility of using different spraying techniques (type of treatment equipment, type and type of spraying devices), as well as the recommendations included in the label of a specific plant protection product. Surface agents require very good coverage of sprayed plants and generally require the use of more spray fluid than systemic agents. In foliar feeding treatments and when combining the use of several chemicals, it is recommended to use increased volumes of spray liquid. With appropriate treatment equipment (e.g. PSP sprayers), the liquid dose can be reduced to 50-100 l ha-1, which should ensure sufficient quality of coverage of the treated plants.

Selection of sprayers

Spray nozzles have a direct impact on the quality of spraying and thus on the safety and effectiveness of plant protection products. Catalogues and general recommendations regarding their use are useful in selecting the appropriate sprayers for individual plant protection treatments. The selection of the atomiser for specific protective treatments should be preceded by getting to know its technical characteristics, and above all information about the type, size of the spray slot, and intensity of the liquid discharge.

Preparation of spray liquid

The intended volume of the liquid should be prepared immediately before the procedure to avoid undesirable physicochemical reactions. The sprayer agitator must be switched on at all times to protect the mixture from precipitation at the bottom of the tank. Before pouring the agent into the tank, read the instructions on the label regarding how to prepare the working liquid and the possibility of mixing the agent with other preparations, adjuvant 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.

Filling the sprayer:

- the sprayer must be filled on an impermeable and hardened surface (e.g. concrete slab), in a place where it is possible to prevent the spreading of spilled or leaked plant protection products;
- the measured quantity of crop protection product should be poured into the partially filled tank with the agitator switched on or in accordance with the instructions for use of the sprayer;
- empty plant protection product containers must be rinsed three times, the contents poured into the sprayer tank and the container should preferably be returned to the seller;
- if possible, it is best to fill the sprayer on a special stand with a biologically active substrate;
- when filling the sprayer on a permeable medium, a thick foil for the collection of spilled or scattered 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 should be collected and deposited at the plant protection product bioremediation site, 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. It starts with an adjuvant to improve the compatibility of the mixture components (if used). Plant protection products are then added (in the correct order, according to their formulation) and topped up with water until the desired volume of the sprayer tank is reached. 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. For the treatment, do not use water with low temperature (taken directly from the deep well), as well as with high hardness and contaminated. Protective treatments may begin when the spray liquid is properly prepared.

7.3. Treatment conditions

Plant protection products should be used in a way that does not pose a threat to the health of humans, animals or the environment, including preventing the spread of plant protection products to areas and objects that are not the target of the treatment.

Treatments with plant protection products should be performed in low wind and rain-free weather and moderate temperature and insolation. Spraying during unfavourable weather conditions (stronger wind, high temperature and low air humidity) may cause damage to plants of other species as a result of the spray liquid being carried to areas not covered by the treatment, and may also result in unintentional poisoning of many beneficial species of entomofauna.

Table 11. presents recommendations for optimal and limiting weather conditions during spraying operations. The recommended air temperatures during treatments are conditioned by the type and mechanism of action of the plant protection product applied and such data

are included in the label texts. For most preparations, optimal effectiveness is achieved at a temperature of 12-20 °C.
Plant protection products can be applied in the open if the wind speed does not exceed 4 m/s. A slight wind, with a speed of 1 to 2 m/s, is also beneficial due to turbulence and better movement of the sprayed liquid among the sprayed plants. In weather conditions close to the upper (wind temperature and speed) or lower (air humidity) limit values, spray nozzles limiting drift (e.g. low drift or ejector) and lower recommended operating pressures should be used for spraying operations.

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

Parameter	Limit values (extreme)	Optimal (most advantageous) values
Temperatures	1-25°C during the treatment	12-20°C during treatment
	up to 25°C the day after treatment	20°C the day after treatment
	not less than 1°C the next night	not less than 1°C the next night
Air humidity	40-95%	75-95%
Rainfall	less than 0.1 mm during treatment	no rainfall
	less than 2.0 mm within 3-6 hours of treatment	
Wind speed	0.0-4.0 m/s	0.5-1.5 m/s

Plant protection products in open areas may be applied using tractor-mounted and self-propelled field or orchard 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 sprayers and self-propelled orchard sprayers at least 3 m away from bodies of water and watercourses and from areas not used for agriculture other than as a target 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.

7.4. Procedure after spraying

After completing each cycle of treatments, remove any remaining working liquid from the sprayer by spraying it on the field or plantation where the treatment was performed, or on your own unused agricultural land, away from drinking water intakes and sewage wells.

The sprayer should be washed thoroughly in the place intended for this purpose. **It is not permitted to pour the liquid remaining after treatment onto the soil or into the sewage system or in any other place that would prevent its collection or pose a risk of soil and water contamination. Washing and rinsing the tank and the liquid sprayer installation should be carried out at a safe distance (no less than 30 m) from wells, water intakes and reservoirs and watercourses.**

Procedure for rinsing the tank and liquid system

- for rinsing, use the smallest amount of water necessary (2-10% of the tank volume or an amount to dilute the liquid remaining in the tank 10 times) - it is recommended to rinse the liquid system 3 times with a small portion of water;
- turn on the pump and, with the inflow to the sprayers closed, rinse all the elements of the liquid system used during the treatment;
- spray the washings onto the area previously sprayed or, if this is not possible, use the remaining liquid in accordance with the recommendations for the management of liquid residues;
- remaining liquid drained from the sprayer should be disposed of using technical devices ensuring biological biodegradation of active substances of plant protection products. Until neutralisation or disposal, liquid residues may be stored in a sealed, labelled and secured container for that purpose.

External sprayer washing

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

Registration of treatments

Professional users of plant protection products are obliged to maintain and store for 3 years documentation regarding the plant protection products they use. 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 documentation also requires the law to indicate the method of implementing the requirements of integrated plant protection by providing at least the reason for performing 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.**

8. PREPARATION FOR HARVESTING, HARVEST, AND STORAGE OF CROPS

The lentil harvest usually falls on the last days of July and the first decade of August. Harvesting is undertaken when the lower pods are brown, the seeds are hard in them and the plants are still green at that time. Lentils characterised by a flaccid stem are prone to lounging, which can cause difficulties in harvesting and contribute to large quantitative and qualitative losses of seed yield. Lentil seeds show a certain tendency to fall off, because the pods break easily. A further difficulty during harvesting is the short shoots of lentils plants and their uneven ripening. The choice of an appropriate term for harvesting is very important because a delayed collection leads to deterioration in the quality of the seeds (severity of infestation by fungal diseases) and changes in colour, which may reduce their commercial value.

The quality of the collection is strongly influenced by the appropriate preparation of the harvester which requires consideration of the following elements:

- setting the minimum cutting height;
- setting the rotational speed of the threshing drum, the retractor and the fan revolutions;
- setting of the working gap between drum and tick;
- setting the opening size of the shutter screens of the conveyor.

The harvester's radiator should be set so that its axis of rotation is in front of the cutting unit (Księżak, Podleśny 2002). The reel fingers should be tilted in the combine harvester's driving direction, which improves the smoothness of the crop feeding. Its rotational speed shall be equal to or slightly lower than the operating speed of the combine harvester. It is also advisable to use lifters for lodged plants. When adjusting the combine harvester, plant moisture, weed infestation and lodging should be taken into account. If the weather is dry and sunny, the seeds may dry out (they may crack during harvesting), then they should be harvested early in the morning. The final coordination of the work units of the harvester, as in the case of harvesting of other plants, should be done during a test run for a distance of 50-100 m.

After threshing, the seeds need to be cleaned and dried to 13–14 % moisture. Seeds intended for sowing must be dried slowly and gradually. Therefore, in dryers it is not allowed to reduce the moisture content of seeds by more than 3% at a time, as they can be damaged. The rule should also be followed: the wetter the seeds, the lower the drying temperature should be. Seeds containing 30% water should be dried at a temperature not exceeding 30°C. After reducing the seed moisture to 25°C and then to 20%, the air temperature can be increased to 35°C and 45°C, respectively. Drying lentil seeds intended for feed should also not take place at too high a temperature, as this may impair the absorption of some nutrients. Seeds can also be dried in an unheated air warehouse or by frequently shovelling a thin layer. Straw stays in the field and enriches the soil with organic mass and nutrients

9. DAMAGE TO LENTIL CROPS CAUSED BY WILD GAME ANIMALS

Hunting damage is damage caused to crops and agricultural produce by wild boars, moose, deer, fallow deer and roe deer, as well as during hunting.

Harm to agricultural crops caused by wild animals is a problem that is still unresolved and presents many difficulties and dissatisfaction in terms of legal, procedural and, above all, methodological aspects related to the valuation of losses and the determination of the amount of compensation to be paid to the farmer. Therefore, for many years efforts have been made to improve legal and methodological solutions in the area of estimating losses in crops and agricultural produce. However, the often changing legal aspects related to estimation do not bring any specific solutions that would allow for quick and objective action by both hunting clubs or animal breeding centres, as well as victims (Flis and Rataj 2017, Flis 2018a, Flis 2018b, Zalewski et al. 2020).

In Poland, populations of wild boar, deer, roe deer, fallow deer, elk, wild geese and cranes have increased significantly in the last decade, causing damage to agricultural crops (Węgorek 2011, Węgorek et al. 2014).

Species of coarse-seeded legumes are very attractive for all species of birds, and of large game, especially for wild boar. Damage caused by wild game is very similar to damage caused by maize sowing. When assessing the damage and visual inspection of the destroyed plantation, it is necessary to determine the measurement sites, draw a sketch of the damage and take photos. In the case of only point damage, the procedure is very simple. The measurement unit (MU) is 1 m2, which can be measured with a frame. In the case of very diverse results, it is proposed to extend the measuring distance up to 20 meters and increase the number of measurements. The determination of plant density in undamaged locations on measuring units should take into account all factors affecting the plant density, such as pests, diseases and atmospheric conditions. In the final estimation of losses, account should be taken of the purpose for which the plantation was established. The optimal solution for the elimination of damage is the use of trial mowing in damaged and undamaged places, especially in crops of little-known species in Poland, which include lentils and chickpeas. In the event of unusual damage to seeds and plants (and in the event of a possible dispute about the amount of compensation), the estimators should seek advice from the Agricultural Advisory Centre.

10. RULES FOR KEEPING RECORDS IN INTEGRATED PRODUCTION

Cultivation of plants in the integrated plant production system is inherently linked to the maintenance 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 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 or may have 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;
- mandatory and control lists;
- test results on residues of plant protection products and levels of nitrates, nitrites and heavy metals in agricultural crops;
- soil and leaf test results;
- certificates of completion of training;
- reports or proof of purchase attesting to the technical functioning of the equipment for applying plant protection products;
- purchase invoices for, among others, plant protection products and fertilisers;
- application for a certificate;
- IP certification.

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

The application form should be completed with information such as:

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

The application must also include the date and signature of the applicant. The 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.

The application must also be accompanied by a copy of the certificate of completion of training in integrated plant production or copies of other documents confirming the qualifications held.

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. When applying for a certificate for more than one plant species, it is required to maintain IP Notebooks individually for each species.

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 stated on the cover. Next, own information must be added.

List of fields in the integrated crop production system – all cultivated varieties submitted for IP certification should be recorded in the field list table.

Field plan with elements increasing biodiversity – the farm plan and its immediate surroundings should be graphically reproduced, maintaining the proportions of individual elements. The farm plan uses the same markings as those used in the list of fields.

General information, sprayers, operators – we note the year in which production was started in accordance with the principles of integrated plant production. Next, tables must be filled in. The bullet points should be filled in with appropriate entries and the information confirmed by ticking the relevant boxes (□). The 'Sprayers' table should be filled in with the required data and the information confirmed by ticking the relevant boxes (□). We also record the names of all sprayer operators performing 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 we list all devices and persons performing treatments, including those provided as services.

Purchased plant protection products – in the table we record the purchased plant protection products (trade name and quantity) intended for the protection of plants for which the notebook is kept. **Monitoring tools, e.g. colour stickers, pheromone traps —** in the table we record the used colour stickers, pheromone traps, etc. and indicate the pests which these tools were intended to monitor.

Crop rotation – the crop rotation table is completed by entering the species and marking the code of the field in which it was used. Crop rotations must be reported for the period (number of years) specified in the methodology.

Seed material / seed – table to be completed by entering information on bought seed material / seed for sowing – variety name, category, qualification level, quantity, plant passport, seed label – if applicable, and proof of purchase (invoice).

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

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

Control observations and record of plant protection treatments — the plant protection tables are the basic element of the IP notebook. The first table, ‘Observations of weather conditions and plant health’, is a detailed register of observations conducted, in which the data indicated in the header is recorded. The need for chemical treatment should also be indicated in this table. 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. The 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. desiccants.

Harvest – in this table we record the amount of crop taken from individual fields.

Hygiene and sanitary requirements – we note whether people who have direct contact with food have access to clean toilets and hand washing facilities, cleaning products and disposable towels or hand dryers. Also the manner of observing the hygiene and health requirements for IP methodologies should be described.

Other mandatory requirements for the protection of plants against pests according to the requirements of the method — a page in the notebook containing space for IP producer’s 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.

11. LIST OF MANDATORY ACTIONS AND TREATMENTS IN INTEGRATED PRODUCTION OF LENTILS

Mandatory requirements (compatibility of 100%, i.e. 11 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	Applying appropriate crop rotation as indicated in the methodology. A break in the cultivation of lentils on the same field should be no longer than three years (Chapter 3.2).	□/□	

2.	Carry out mechanical weed control measures before sowing (Chapter 5.1.2).	□/□	
3.	Sowing within the period appropriate for the region concerned, in line with the appropriate standard and parameters of sowing (Chapter 3.6).	□/□	
4.	Application of fertilisation with macro- and microelements at appropriate times and doses depending on the type and pH of the soil after carrying out a nutrient balance confirmed by documents (Chapter 3.5).	□/□	
5.	In the control of weeds, primarily agrotechnical methods should be used, and in the case of chemical protection, the proper use of herbicides in the appropriate dose, taking into account the level of weed sensitivity (Chapter 5.1.3).	□/□	
6.	Monitoring of the field from the beginning of emergence to the beginning of maturation, at least 1x a week, the occurrence of diseases (seed blight, scleroderma, grey mould, fusarial lentil decay, lentil leaf ascochytosis) (Chapter. 5.2.1).	□/□	
7.	Systematic monitoring of the field from the beginning of the east to the beginning of maturation, a minimum of 1x per week, the presence of pests (yarns, aphids, pod-shaped beetle, soil pests, bishop bug, lucerne bug) using appropriate methods (Chapter 5.3).		
8.	Use of plant protection products after exceeding the damage threshold for diseases and pests (Chapter 5.3.4).	□/□	
9.	At least one treatment with biological plant protection products, if registered (seed treatment or plant spraying during the growing season) – confirmed with a purchase invoice (Chapters 6.1, 6.2).	□/□	
10.	Placing mason bee houses or mounds for bumblebees in the amount of at least one per 5 ha, and in the case of larger plantations, a few (Chapter 6.4).	□/□	
11.	Creating suitable conditions for the presence of birds of prey, i.e. setting up at least one resting pole per 5 ha and, in the case of larger plantations, several poles (Chapter 6.3).	□/□	
Total points		□/□	

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

12. CHECKLIST FOR AGRICULTURAL CROPS

Basic requirements (100% compliance, i.e. 28 points)			
No.	Control points	YES/NO	Comment
1.	Does the producer produce and protect the crops according to detailed methodologies approved by the Main Inspector?	□/□	
2.	Does the producer have up-to-date IP training confirmed by a certificate, subject to Articles 64(4), (5), (7) and (8) of the Plant Protection Products Act?	□/□	
3.	Does the producer apply plant protection products only from the list of IP-recommended products?	□/□	
4.	Are all required documents (e.g. methodologies, notebooks) present and kept on the farm?	□/□	
5.	Is the IP Notebook kept correctly and up to date?	□/□	
6.	Does the producer systematically conduct control observations of the crops and record them in the notebook?	□/□	
7.	Does the producer deal with empty packaging of crop protection products and products that are expired in accordance with the applicable legal regulations?	□/□	
8.	Is chemical protection of crops replaced by alternative methods wherever justified?	□/□	
9.	Is chemical plant protection carried out based on risk thresholds and the alerting of harmful organisms (wherever possible)?	□/□	
10.	Are 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 authorised for IP and used in a given crop or 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 area?	□/□	
13.	Were the plant protection treatments carried out under appropriate conditions (optimal temperature, wind below 4 m/s)?	□/□	
14.	Is the rotation of the active substances of the crop protection products used for the treatments respected, if possible?	□/□	
15.	Does the producer limit the number of treatments and the amount of crop protection products used to a necessary minimum?	□/□	
16.	Does the producer have measuring devices to precisely determine the quantity of the measured plant protection agent?	□/□	
17.	Are the conditions for safe use of the agents respected, as set out	□/□	

Basic requirements (100% compliance, i.e. 28 points)			
	on the labels?		
18.	Does the producer comply with the label instructions concerning the observance of precautions related to environmental protection, i.e. e.g. the observance of buffer 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 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 crop 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.	**Control points**	**YES/NO**	**Comment**
1.	Were the plant varieties grown selected for Integrated Plant Production?	□/□	
2.	Is each box marked according to the entry in the IP notebook?	□/□	
3.	Did the producer perform all the necessary agrotechnical procedures in accordance with IP methodologies?	□/□	
4.	Is the recommended catch crop used in cultivation?	□/□	
5.	Are steps taken on the holding to reduce soil erosion?	□/□	

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

Recommendations (min. implementation 20%, i.e. 2 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	Are soil maps drawn up for the holding?	☐/☐	
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 plant protection products spilling or scattering and do they have the tools to counteract such a threat?	☐/☐	
6.	Does the producer restrict access to the keys and 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 deepen their knowledge through Integrated Plant Production meetings, courses or conferences?	☐/☐	
	Total points		

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