PIORIN MAIN INSPECTORATE OF PLANT HEALTH AND SEED INSPECTION

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Methodology for the integrated production of chickpeas (*Cicer arietinum L.*)

(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 Inspection

Warsaw, March 2025

Approved by
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Methodology developed as part of task 1.6.1
'Drawing up and updating of Integrated Plant Protection programmes for tobacco and hops, and the drawing up of methodologies for the integrated production of lentils and chickpeas'
financed by the Ministry of Agriculture and Rural Development

ISBN:
Electronic publication

https://doi.org/10.26114/mon.iung.2024.12.01

IUNG-PIB Publishing
Department of Science Communication, IUNG-PIB in Puławy

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1. PREFACE

Chickpeas (*Cicer arietinum* L.) were cultivated in the Middle East as early as 7 500 years ago and spread around the world in the 17th century. In antiquity, medicinal properties were attributed to it and there was a belief that chickpeas stimulate lactation, have diuretic properties and help excrete kidney stones.

Chickpeas are a warm-climate species and are popular in countries with low precipitation (Merga and Haji 2019). Between 2010 and 2012, the average area of cultivation of this species in the world was 12.4 billion hectares, and it increased in the 2020s (FAO 2019). Chickpea is currently cultivated in over 50 countries, mainly in the Indian Peninsula, the Mediterranean basin, Australia, Africa, the Americas, the Balkans, Slovakia, Pakistan, Syria, and Tunisia (Merga and Haji 2019, Iqbal et al. 2006, Naghavi and Jahansouz 2005, Viveros et al. 2001). Due to its characteristics, the cultivation of this species fits perfectly into the system of sustainable agriculture, especially organic farming. The average yield of chickpeas is approximately 850 kg/ha^{-1} (Canci and Toker 2009, FAO 2019, Frimpong et al. 2009, Singh et al. 1997, Özdemir and Karadavut 2003). There are two different types of chickpeas: desi and kabuli. The desi variety is distinguished by pink flowers and anthocyanin pigmentation of the stems. The kabuli variety is characterized by white flowers, the absence of anthocyanin pigmentation of the stems, and white or beige seeds in the shape of a ram's head (Moreno and Cubero 1978). Desi chickpeas account for approximately 80–85% of the total chickpea area and are cultivated mainly in Asia and Africa (Pande et al. 2005).

Thanks to the ability to fix atmospheric nitrogen, the chickpea does not require fertilisation with this component and it leaves a significant amount of it in the soil after harvesting (Pociejowska et al. 2013). It is also included among the species that have a positive impact on the natural environment and limit the production of greenhouse gases. Furthermore, the trend to reduce the consumption of animal products in favour of food of plant origin results in a growing interest in legume seeds, including chickpeas. The nutritional value of chickpeas (per 100 grams of seeds) stems mainly from their high protein (20 g), fat (6 g), carbohydrate (62 g) and fibre (12 g) content (Frimpong et al. 2009, Wood et al. 2010, Lykhochvor and Pushchak 2019, Maheri-Sis et al. 2008). Chickpeas are also rich in vitamins: A, B1, B2, B6, B7, C, K, PP, and macro- and micro-elements such as selenium, magnesium, potassium, manganese, calcium, boron, iron and silicon (Iqbal et al. 2006, Lampart-Szczapa 1997, Ohr 2003). Because of its nutritional value, the chickpea is one of the most valued species in the world. Its composition and health value make it an excellent substitute for meat. Chickpea seeds have a high energy value as 100 g of the product provides about 380 kcal; however, due to their high fibre content, even a small amount is enough to satisfy hunger. The high amount of insoluble fibre stabilises blood sugar levels and reduces the absorption of carbohydrates. Their low glycaemic index (IG 30) make chickpeas a good addition to the diet of those struggling with diabetes and insulin resistance. Chickpeas are also a source of essential amino acids, unsaturated fatty acids and folic acid.

Because of their nutritional and health properties, legumes are called ‘super foods’ and referred to as the protein of the future. In addition, plant-based products form the basis of the food pyramid in the Double Pyramid model developed by the Barilla Centre for Food & Nutrition.

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 (PPP) 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 with a view to reducing the use of pesticides. The provisions of this Regulation place a strong emphasis on, among other things, the use of crop rotation, the cultivation of appropriate varieties, compliance with optimum agronomic timing, the use of appropriate agrotechnology, fertilisation and the 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 counselling.

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

The list of plant protection products authorised in Poland is published in the register of plant protection products. Information 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 .

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 specified on the label. The stipulated doses and the permitted number of treatments must not be exceeded. Plant protection products must only be applied to the areas and facilities targeted by the treatment, i.e. they must not spread to other areas during application.

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

Such areas are most often designated in the vicinity of reservoirs and watercourses and 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 facility 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 must 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 their correct application. The holders of equipment for the use of plant protection products are obliged to carry out periodic tests confirming its technical fitness. The first inspection of a new sprayer must be 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 inspection obligation.

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

Filling out the mandatory IP Notebook in the system 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 (IP) 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.

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

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. The technical rules under the integrated production scheme are IP methodologies approved by the Main Inspector for Plant Health and Seed Inspection and published on the website administered by the Main Inspectorate for Plant Health and Seed Inspection ().

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 Online Pest Signalling Platform at

2.3. Certification rules

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

The notification of the intention to apply integrated plant production must be made annually by the plant producer 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 scheme is open to all producers. Notification of the intention to participate in the scheme may be submitted on paper by post, electronically, or in person.

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

Following the notification, the agricultural producer is obliged to cultivate crops according to the method of integrated plant production for the notified plant and to document their actions in the IP Notebook in detail. A model notebook is included in the Regulation of the Minister for Agriculture and Rural Development of 24 June 2013 on documenting activities related to integrated plant production.

The certification body inspects plant producers who follow the principles of integrated plant production. The inspections cover in particular:

- completion of IP training;
- compliance with the production methodologies approved by the Main Inspector for Plant Health and Seed Inspection;
- fertilisation applied;
- keeping 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 fewer 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 the integrated plant production principles. The tests are carried out in laboratories accredited in the relevant scope pursuant to 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 plant producer attests that the integrated plant production principles are followed. In order to obtain the certificate, the producer must:

- complete training in integrated plant production and hold a certificate of completion of that training, subject to Article 64(4), (5), (7) and (8) of the Plant Protection Products Act;
- produce and protect plants in line with the detailed methodology approved by the Main Inspector available on the website administered by the Main Inspectorate for Plant Health and Seed Inspection;
- use fertilisation based on the actual plant nutritional needs determined on the basis of, in particular, the analysis of the soil and plants;
- document the correct conduct of activities related to integrated plant production;
- follow hygiene and health rules in plant production, particularly those defined in the methodologies;
- no maximum permissible residues of plant protection products and levels of nitrates, nitrites, and heavy metals have been exceeded in plant and plant product samples collected for testing;

- adhere to the requirements concerning plant protection against harmful organisms, particularly those specified in methodologies, during plant production.

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

A plant producer who has obtained a certificate attesting to 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 for Plant Health and Seed Inspection.

2.4 Hygiene and health rules

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

A. Personal hygiene of employees.

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

B. Hygiene requirements for crops prepared for sale

The plant producer must take appropriate measures to ensure that:

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

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

A producer under the integrated plant production scheme must 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 contamination or human health risks, e.g. through the presence of mycotoxins;
- hazardous waste and substances are not stored together with crops prepared for sale.

3. AGRONOMIC REQUIREMENTS

3.1.Habitat requirements

Chickpeas can be successfully grown in areas with low and infrequent rainfall, i.e. in north-western, central and western Poland. This species is a thermophilic plant and for this reason, as well as given its high light requirements, its cultivation in our country is relatively poorly spread. Nonetheless, as many experiments have shown, the sum of effective temperatures does not determine the success of the cultivation of this species. The optimum daytime temperature during the growing season is between 21 and 29 °C and around 18 °C at night. Temperatures above 35 °C and below 15 °C can cause leaves, flowers or pods to wilt. Chickpeas are quite resistant to spring frosts, and in the event of damage to the apical meristem, the plants grow back. However, larger temperature drops during the flowering period can cause damage and flower wilting. At low temperatures and in short-day conditions, the chickpea can delay maturation and prolong the generative development phase. In Poland, the vegetation period lasts 120–125 days.

Chickpeas, like other legumes, have the highest demand for water during the period of swelling and germination of seeds as well as during the formation of flowering buds and at the beginning of flowering. The occurrence of drought in spring causes uneven emergence, poor growth, and the subsequent limitation of flowering and formation of pods. The second period of increased water demand runs from the end of June and in July. However, the sum of precipitation over 760 mm adversely affects the yield of this species and a large amount of rainfall during ripening prolongs the vegetation of plants and causes uneven ripening of seeds. The water use efficiency of this species when grown for seeds ranges from 1.1 to 15.7 kg $ha^{-1}mm^{-1}$. An important feature of chickpeas is the ability to inhibit growth and development in drought conditions, which can continue as soon as humidity conditions improve.

Chickpeas can be grown in different types of soils. Its yields are favourable on permeable, moderately compact, nutrient-rich soils that warm up quickly. The soil optimal for chickpea cultivation is clay (but not heavy and wet) soil with a pH ranging from slightly acidic to alkaline (5.7–7.2) and with a high water retention capacity. Soils should have adequate air–water ratio and be of good structure. Chickpeas should not be cultivated on wetlands, as high moisture contributes to the rapid growth of biomass and can limit the formation of pods. Soil that is too dry should be avoided too. The plant is extremely sensitive to soil salination, which can inhibit its growth.

3.2.Crop rotation

Chickpeas are best grown after cereals in the third and fourth year following root crops, on manure. Growing sites immediately after root crops should be avoided, because such conditions can lead to the formation of a large vegetative mass, which limits the formation of pods and exposes the plantation to stronger damage by pathogens and pests. This species should not be cultivated in succession with other species of large-seeded or small-seeded legumes either. No more than 20–25% of this species should be used in crop rotation because the occurring bacteriophages may destroy the rhizobia. In addition, emerging plants are more affected by damping off and damaged by weevils. A site after the cultivation of chickpeas on compact soils may be used under winter wheat, and on lighter soils winter barley or spring species may be sown in spring. In cereal rotation with winter crops, the sowing of non-legume catch crops is advisable after harvest (Table 1). The cultivation of catch crops increases the content of organic matter, reduces field weeding and nitrogen loss into groundwater.

Table 1. Standards and times for the sowing of catch crops

Catch crop plant species	Sowing time	Sowing quantity
White mustard	until 15.08	20
Phacelia		10
Sunflower		35
Japanese radish		25

Rapeseed		15
Reversed clover		10
Polybra turnip	until 30.08	3

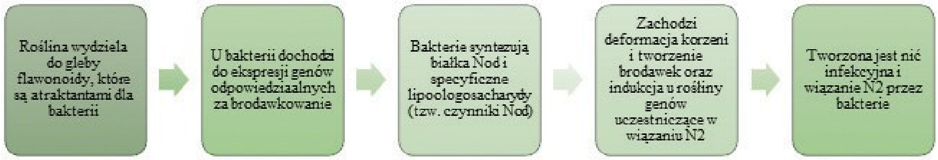
The cultivation of chickpeas increases biological activity in soil. The relatively strong root system contributes to the loosening of the subcutaneous layer and thus facilitates deeper rooting of follow-on plants and enriches the soil with nitrogen, ranging from 40 to 60 kg/ha^{-1} N, with the kabuli variety showing a higher N-binding potential than desi. In addition, the cultivation of this species improves the phytosanitary state of the soil, thereby reducing the infestation of follow-on plants (cereals) by soil-borne pathogens. This is particularly important in simplified cereal rotations.

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 in biomass. Ammonia is absorbed by plants and converted into amino acids and other nitrogen compounds. Ammonium ions (NH_4^+) present in the soil are oxidised through nitrification to nitrites (NO_2^-) and then to nitrates (NO_3^-), which are microbiologically denitrified again to N_2, thus closing the cycle. Biological nitrogen fixation can only occur through soil bacteria capable of fixing nitrogen with the use of nitrogenase, an enzyme responsible for reducing the nitrogen molecule (Pociejowska et al. 2013). Nitrogenase is only active under anaerobic or extreme oxygen conditions. In the natural environment, there are two groups of bacteria capable of binding nitrogen: free-living assimilators and symbiotic bacteria. The free-living bacteria able to assimilate atmospheric nitrogen are: *Azotobacter*, *Azotococcus*, *Azospirillum*, *Beijerinckia*, *Derxia*, *Clostridium*, *Rhodobacter*, *Anabaena* and *Nostoc* (Tin and Branch 2016). These microorganisms are commonly found in the natural environment (soil, water, plants) but their atmospheric nitrogen-fixing efficiency is not high (a dozen or so kg N/ha/year). In addition, during the process of binding atmospheric nitrogen, free-living assimilators do not secrete ammoniacal nitrogen, which could be used by plants, outside the cell (Martyniuk 2008). A group of bacteria that can assimilate nitrogen and form association systems with plants (both wild and cultivated) are *Azospirillum* bacteria, which are quite common in the environment. However, like wild assimilators, they do not make ammonium ions available to plants (Gałązka et al. 2015).

Due to the symbiosis of the legumes and rhizobia, nitrogen in its assimilable form is transferred to the plant. The nitrogen-fixing bacteria living symbiotically with legumes are referred to as ‘rhizobia’. The name is derived from the name of the first bacteria analysed in this group — *Rhizobium*. Microorganisms with primary N-fixing capacity include: *Bradyrhizobium*, *Azorhizobium*, *Mesorhizobium*, *Rhizobium* and *Ensifer*. Among the bacteria that have acquired these skills are: *Burkholderia*, *Devosia*, *Cupravidus*, *Ochrobactrum*, *Microvirga*, *Methylobacterium*, *Phyllobacterium* and *Shinella*. This bacteria group may also be called root nodule or nitrogen bacteria.

Rhizobia enter the roots through the so-called infection thread and cause the formation of nodules 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, transform into Bacteroides and begin to assimilate nitrogen, which takes place in several stages (Figure 1).



The plant secretes flavonoids to the soil that attrac
the bacteria

The bacteria express genes responsible for the
nodulation

The bacteria synthesise Nod proteins and specific
lipooligosaccharides

Root deformation, nodulation and induction of ge
involved in fixing N_2 occur in the plant

N_2 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 nodules indicates an active nitrogen fixation process. This process is most intense before flowering and during the flowering period of plants. After its completion, the symbiosis weakens. The symbiosis of bacteria with legumes is specific, because each species can only co-exist with a specific species of rhizobia (Podleśna 2018) (Table 2). Plants are able to recognise a chemical signal from a given bacterial species and select the optimal symbiont (Heath and Tiffin 2009).

Table 2. Examples of legumes and their bacterial symbionts

Plant	Bacteria
Bird's-foot	*Bradyrhizobium* sp.
Soybean	*Bradyrhizobium japonicum*
Peas Green peas Horse bean Vetch Field bean	*Rhizobium leguminosarum* bv. viceae
Bean	*Rhizobium leguminosarum* bv. phaseoli
Clovers	*Rhizobium leguminosarum* bv. trifolii

Lucerne Melilotus Fenugreek	*Sinorhizobium meliloti*
Lotus	*Mesorhizobium loti*
Chickpeas	*Mesorhizobium ciceri; Mesorhizobium Mediterraneum*

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 advisable when:

- a given legume species has not been grown in the area for a long time (4–5 years),
- the pH of the soil is acidic,
- the area in which the species is to be sown is to be rehabilitated,
- legumes are sown on uncultivated agricultural land,
- a non-native plant species, e.g. soybean, is cultivated.

The vaccine should contain 10^7–10^9 colony-forming units (CFU) of live bacteria per one gram of preparation. In addition to the selection of the preparation adequate for the species of sown plant, attention should be paid to the correct use of the preparation. Vaccines containing rhizobia are most commonly used in pelleting the seeds before sowing. The rhizobia are sensitive to light, therefore storage of the preparations in sunlight should be avoided. Seed pelleting should be carried out over a possibly short period of time and the treated seeds should not be left in sunlight. Such a preparation should also not be frozen or exposed to high temperatures (above 40 °C). **If chemical treatment of plants, e.g. with fungicides, is planned before sowing, then the treatment must be carried out first and the microbiological preparation must be applied afterwards** (IUNG-PIB Guide 2023).

The inoculation of chickpeas uses *Mesorhizobium* genus bacteria, mainly *M. ciceri* and *M. mediterraneum* (Wanjofu et al. 2022). For this species, the symbiotic N_2 fixing 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. Where they are limited, symbiosis is less efficient (Lusiba et al. 2022).

Symbiotically bound nitrogen accounts for 70–80% of the estimated amount of 139–170 10^6 tonnes of nitrogen entering the global cycle annually. It is also estimated that the symbiosis of legumes with bacteria provides around 44–60 million tonnes of nitrogen per year, which is almost half of the total amount used in agriculture. The nitrogen fixation capacity varies according to the plant species and to environmental conditions (Table 3).

Table 3. Nitrogen fixation indices of selected legume species (based on a number of sources)

Species	**Amount of nitrogen fixed**
Chickpeas	18–78 kg N/ha^{-1}
Lupin	43–130 kg N/ha^{-1}
Narrow-leaved lupin	165 kg/ha^{-1}, overground parts of plants
Yellow lupin	38 kg N/t^{-1} DM, overground parts of plants
Field bean	110 kg N/ha^{-1} 151 kg/ha^{-1}, overground parts of plants
Lucerne	21–180 kg N/t^{-1} DM, overground parts of plants
Clover	18 kg/t^{-1} DM, overground parts of plants
Red clover	34–41 kg N/t^{-1} DM, overground parts of plants
Peas	150 kg/ha^{-1}, overground parts of plants

Garden peas	35 kg N/t^{-1} DM, overground parts of plants
Bird's-foot	37 kg N/t^{-1} DM, overground parts of plants
Soybean	175 kg/ha^{-1}, overground parts of plants 36 kg/t^{-1} DM, overground parts of plants
Lentil	109–136 kg N/ha^{-1}
Bean	65 kg/ha^{-1}, overground parts of plants

The amount of nitrogen fixed by rhizobia allows for a significant reduction in the use of mineral fertilisers. The nitrogen used is not used by cultivated plants and about 25 % is leached during the growing season, which has an impact on the state 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 agricultural benefits of biological nitrogen fixation:

- the integrated cultivation of legumes promotes the formation of resilient cropping systems;
- increased availability of nitrogen for follow-on crops;
- reduced use of mineral fertilisers;
- reduced carbon footprint;
- support for sustainable agriculture;
- stabilisation of food production over time;
- the cultivation of legumes has a positive effect on the yields of rotation crops and on the nitrogen content of grains and seeds;
- a positive effect on soil quality;
- enhanced plant and microbial biodiversity;
- it prevents water pollution and eutrophication;
- it reduces NO_2 emissions to the atmosphere.

The process of fixing atmospheric nitrogen is influenced by many factors, including: extreme temperatures, soil pH, salinity, toxic chemicals, mineral fertilisers, fungicides, antibiotics and heavy metals (Paśmionka 2017). These factors can affect the survival of rhizobia, their growth and the ability to enter into symbiosis with legumes. In addition, certain factors influence the process of plant–bacterium symbiosis establishment itself or its effectiveness. High level of nitrogen in the soil inhibits the formation of nodules and the binding of atmospheric nitrogen. Salinity of the soil can inhibit nitrogenase activity and, consequently, weaken the nitrogen fixation process. A soil pH (below 4.8) may also reduce bacterial survival, node formation, nitrogenase activity, and weaken the attachment of rhizobia to root hair. Some pests, e.g. weevil, Meloidogyne javanica, can destroy already formed nodules on the roots. The procedure of using bacterial vaccines should be carried out very carefully, because improperly performed inoculation or not enough bacteria present in the preparation will weaken the process of establishing the symbiosis.

3.4. Soil cultivation

Cultivation after harvesting previous cropping is the same as in the case of cultivation of other species sown in the spring. If catch crops have not been sown, ploughing or stubble cultivating (with a rigid-tine cultivator called subsoiler) must be carried out and harrowing must be carried out several times to destroys emerging weeds. In the late autumn, deep prewinter ploughing should be carried out. A reversible or pendulum plough may be used, which reduces the cost of the procedure, but above all reduces the compacting of soil on headlands with the wheels of the tractor.

In spring, the first treatment to reduce water evaporation and moisture losses should be carried out as early as possible. The soil should be treated immediately before sowing, preferably with a cultivation set that ensures crushing of lumps, levelling of the field and loosening of the soil to the depth of seed sowing, i.e. 6–10 cm on compact soils and 6–8 cm on lighter soils. This allows for the seeds to be placed at the appropriate depth. It also contributes to the rapid and even emergence of the plants and to the deep rooting of the plants, thus reducing the sensitivity of the plants to temporary droughts. Cultivation procedures should also be differentiated depending on the state of the soil after winter and the method of sowing the seeds. In most cases, sowing is carried out by a cereal seed drill equipped with sowing apparatus for coarse seeds and with heavily weighted coulters. The use of a cultivation and sowing unit allows for sowing to start immediately after the spring levelling of the field with a harrow or without this treatment. When sowing with a colter seed drill intended for deep sowing, the soil must be levelled with harrows. Chickpeas may also be sown with precision seed drills, which guarantee a much greater uniformity of sowing than cereal seed drills. Cultivation procedures should be carried out at appropriate soil moisture so as not to spray or compact the soil too much. It is also important to level the surface, even though chickpeas have a rigid stem, because it allows for low installation of the cutting units of harvesting machines.

3.5 Fertilisation

The effectiveness of the cohabitation of chickpeas with rhizobacteria and the proper use of nutrients is determined by the soil pH. The optimum pH for this species ranges from 5.7 to 7.2. There is a high concentration of aluminium ions on acidic soils, which can inhibit root growth and cause poor development of rhizobia. Acidic soils with a pH below 5.5 should preferably be limed during post-harvest cultivation treatments (Table 4). If the magnesium content is lower than 6 mg per 100 g of the soil, magnesium lime should be used. Magnesium fertilisers of 40–80 kg/ha_{-1} Mg should be applied to soils with a pH close to neutral but low in magnesium.

Phosphorus and potassium improve the growth and development of chickpeas and the symbiotic fixation of free nitrogen by rhizobia. This species, like other legume species, assimilate phosphorus and potassium from forms that are difficult to absorb. The doses of fertilisation with these components should be determined as for other cultivated plant species, primarily depending on the expected yield and the content of these components in the soil. Due to the possibility of leaching, these fertilizers should be applied in the spring before soil conditioning treatments (Tables 5, 6).

Chickpeas, like other legume species, can fix atmospheric nitrogen. On sites where the content of $N\text{-}NO_3^-$ in the soil in a layer of up to 30 cm is lower than 22 kg/ha_{-1}, it is recommended to use 25–35 kg/ha_{-1}, because during the initial growth period, until the symbiosis starts, the plants may suffer from a shortage of nitrogen. However, on better sites, fertilisation with this component is not required. Higher nitrogen doses and a higher amount of nitrogen in the soil can reduce the binding of this element through symbiosis and delay the ripening of the plants. This fertiliser must be applied immediately before sowing the seeds. On sites with low levels of boron and molybdenum, the use of these ingredients is justified. 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 chickpea budding at doses of 0.04 kg/ha_{-1} molybdenum (Mo) and 0.2 kg/ha_{-1} boron (B). These elements have a positive effect on the photosynthesis process in chickpeas and, as a result, on the seed yield.

Table 4. Calcium dosage (CaO in t/ha-1)

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

Table 5. Phosphorus dosage (P_2O_5 in kg/a-1)

Soil complex	Phosphorus content in soil				
	very	low	medi	high	very 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 (10)	60	35	20	15	–

Table 6. Potassium dosage (K_2O in kg/ha-1)

Soil complex	Potassium content in soil				
	very	low	medi	high	very high
Defective wheat (3)	40	30	25	20	0
Very good rye (4)	40	30	25	20	0
Good rye	40	35	30	30	20
Mountain wheat (10)	60	35	35	30	0

3.6. Sowing

For sowing chickpeas, healthy, undamaged seeds with a high germination capacity should be used, which are to be sown in the first decade of May, when the risk of exposure of plants to spring frosts is reduced, and the date of sowing depends on the region of the country. According to the recommendations, depending on the different agro-ecological conditions, around 100 seeds should be sown per 1 m^2. It is important that the soil at 5–8 cm of depth reaches a temperature of about 8 °C, as such a temperature promotes the rapid germination of seeds and the emergence of seedlings, which reduces the risk of exposure to soil pathogens. If the spring is warm, the plants emerge quite quickly and after about eight weeks the first flowers appear, followed by pods.

Chickpeas are most often sown in rows with a spacing of 20–30 cm, but a wider spacing of 50 to 60 cm can also be used. The wider spacing allows for mechanical treatments in the inter-rows and increased air movement between rows may limit the occurrence of leaf diseases. The depth of sowing depends on the genotype (‘desi’ should be sown 2–3 cm shallower than ‘kabuli’) and the moisture content and compactness of the soil. The optimum sowing depth for chickpeas grown under appropriate moisture conditions is 5–7 cm, and in dry conditions, it may be increased to 8–10 cm. Such soil covering of seeds has a beneficial effect on the germination and development of the root system.

The recommendations for preparation of chickpea seeds for sowing are consistent with the guidelines for other legumes. The chickpea is capable of fixing atmospheric nitrogen, but it is important to vaccinate the seeds with the appropriate *Mesorhizobium* strain. Using the vaccine increases the intensity of nitrogen fixation by rhizobia such as *Rhizobium leguminosarum*. Seed treatment is necessary because Polish soils are not naturally rich in active strains colonising its roots. This treatment is particularly beneficial in sites where chickpeas have not been grown for a long time or the soil is acidic. 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 chickpeas in a given field was longer than 4–5 years, such a bacterial vaccine should also be used. If the use of a bacterial vaccine is planned, the seeds should be treated with seed preparation approximately two weeks before sowing and immediately before sowing with a bacterial vaccine.

Seed drill calibration must be carried out prior to sowing. The amount of sowing is calculated on a case-by-case basis, taking into account the actual quality characteristics of the seeds, using the formula:

$$\text{sowing (kg/ha)} = a \times b/c$$

where: a — planned plant density
b — weight of 1000 seeds,
c — seeds value in use (purity x germination capacity)

It is also recommended to leave access paths for spraying units used for the plantation treatments. If heavy rain falls after sowing and a crust forms, light harrows may be used, but in such a case it is preferable to use a light crushing roller. Precision seed drills, tine seed drills intended for large seeds or groove seed drills for top-sowing should be used for the 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.

Higher cumulative yields of kabuli and desi chickpeas have been observed with cereals compared to those cultivated on their own (Table 7) (Prince, Bojarczuk 2020). A higher yield of seeds of both varieties of chickpeas is ensured by its cultivation with oats compared to growing it with barley or on its own. Higher yields of seeds of both varieties of chickpeas can be achieved through their cultivation on their own than when sown with support plants. On average, both when sown on its own and with cereals, the desi chickpeas’ yields are higher than those of the kabuli variety (Table 7).

The yield share of desi chickpeas seed sown with support plants is lower than that of kabuli chickpeas (Table 8).

A much higher number of pods, seeds and weight on the plant, the weight of a thousand seeds characterise chickpeas grown on their own than with cereals (Table 9, 10). Regardless of the method of sowing, the kabuli chickpea is characterised by a greater mass per 1000 seeds, seed mass and the number of pods on the plant than the desi variety (Table 9, 10). Growing both forms of chickpeas with spring cereals results in a slightly higher formation of the first and last pod on the shoot, but does not affect the height of the plants (Table 11). Regardless of the sowing method, the kabuli chickpeas seeds have a higher protein and phosphorus content, while the desi variety is characterised by a higher content of crude fibre and fat (Table 12). In addition, both forms are characterised by a similar potassium content, regardless of the method of sowing. Where the precipitation is limited during the growing season, there is a higher concentration of protein and fat in the seeds of both forms of chickpeas, but also a greater accumulation of fibre. Growing chickpeas with cereals has a beneficial effect on the accumulation of protein and phosphorus in the seeds, but does not have a significant effect on the amount of fat, fibre and potassium. Due to the level of yield as well as the nutritional value of the seeds obtained under integrated production, it is not recommended to sow this species with other crops.

Table 7 Total yield of chickpea seeds and support crops, and weight of 1000 chickpea seeds depending on the type of sowing

Sowing method	**Seed yield (t/ha-1)**			**Weight of 1 000 seeds [g]**		
	2017	**2018**	**Average**	**2017**	**2018**	**Average**
Kabuli chickpeas, sown on their own	0.5	2.2	1.3	231.	328	279.
Kabuli chickpeas + barley	0.9	2.3	1.6	174.	268	221.
Kabuli chickpeas + oat	1.4	2.6	2.0	173.	265	219.
Desi chickpeas, sown on their	0.4	2.5	1.5	124.	213	169.
Desi chickpeas + barley	0.8	2.9	1.8	108.	176	142.
Desi chickpeas + oat	1.3	3.0	2.1	106.	170	138.
Average	0.9	2.6		153.	236	

Table 8. Share of chickpeas and seed yield depending on the type of sowing

Sowing method	**Share of chickpeas (%)**			**Seed yield (t/ha-1)**		
	2017	**2018**	**Aver**	**2017**	**2018**	**Aver**
Kabuli chickpeas, sown on their own	–	–		0.56	2.20	1.38
Kabuli chickpeas + barley	3.3	32.5	17.9	0.03	0.76	0.39
Kabuli chickpeas + oat	2.3	30.7	16.5	0.03	0.81	0.42
Desi chickpeas, sown on their own	–	–		0.49	2.51	1.5
Desi chickpeas + barley	2.5	36.8	19.6	0.02	1.09	0.56
Desi chickpeas + oat	1.8	34.0	17.9	0.02	1.02	0.52
Average	2.47	33.5		0.19	1.40	

Table 9 Number of pods on the chickpea plant depending on the method of sowing (pcs.)

Sowing method	2017	2018	Average
Kabuli chickpeas, sown on their own	3.11	5.10	4.10
Kabuli chickpeas + barley	1.42	2.45	1.94
Kabuli chickpeas + oat	1.31	1.90	1.60
Desi chickpeas, sown on their own	2.80	6.20	4.50
Desi chickpeas + barley	1.02	1.68	1.35
Desi chickpeas + oat	0.98	1.20	1.09
Average	1.77	3.09	

Table 10. Weight and number of seeds per chickpea plant depending on the type of sowing

Sowing method	Number of seeds on the plant			Seed weight per plant (g)		
	2017	2018	Average	2017	2018	Average
Kabuli chickpeas, sown on their	1.12	3.90	2.51	0.42	1.60	1.01
Kabuli chickpeas + barley	0.61	2.10	1.36	0.31	0.56	0.43
Kabuli chickpeas + oat	0.40	1.48	0.94	0.27	0.40	0.33
Desi chickpeas, sown on their	1.17	5.40	3.28	0.38	1.41	0.89
Desi chickpeas + barley	0.54	1.55	1.04	0.22	0.22	0.22
Desi chickpeas + oat	0.38	1.03	0.70	0.22	0.19	0.20
Average	0.70	2.58		0.30	0.73	

Table 11. Height to the first and last pod and the top of the chickpea plant (cm)

Sowing method	To the first pod			To the last pod			To the top		
	2017	2018	Average	2017	2018	Average	2017	2018	Average
Kabuli chickpeas — sown on their	35.0	40.2	37.6	36.2	40.5	38.4	38.2	46.0	42.1
Kabuli chickpeas + barley	36.1	42.4	39.3	36.9	43.0	40.0	38.9	47.0	42.9
Kabuli chickpeas + oat	36.9	43.3	40.1	37.4	44.0	40.7	40.0	46.0	43.0
Desi chickpeas — sown on their	33.2	38.4	35.8	34.2	38.9	36.6	36.8	44.1	40.4
Desi chickpeas + barley	34.0	39.8	36.9	34.8	40.1	37.4	37.2	45.2	41.2
Desi chickpeas + oat	34.8	40.7	37.8	35.3	40.9	38.1	37.7	45.9	41.8
Average	35.0	40.8		35.8	41.2		38.1	45.7	

Table 12. Protein, fat and fibre content of chickpea seeds depending on the method of sowing (g/kg-1DM)

Sowing method	Protein			Fat			Crude fibre		
	2017	2018	Average	2017	2018	Average	2017	2018	Average
Kabuli chickpeas, sown on their own	262.5	251.1	256.8	54.2	53.8	54.0	51.8	42.9	47.4
Kabuli chickpeas + barley	287.5	261.0	274.2	54.8	54.2	54.5	52.7	43.1	47.9
Kabuli chickpeas + oat	287.5	264.2	275.8	55.3	53.8	54.6	52.4	43.9	48.1
Desi chickpeas — sown on their	206.3	198.0	202.2	57.0	56.1	56.6	52.2	43.8	48.0
Desi chickpeas + barley	218.8	204.1	211.4	57.4	55.9	56.6	53.1	44.4	48.7
Desi chickpeas + oat	237.5	205.0	221.2	56.2	56.4	56.3	53.4	44.9	49.1
Average	250.0	230.6		55.8	55.0		52.6	43.8	

4. CULTIVATION

Chickpea is an annual, self-pollinating and diploid (2n=2x =16) crop with a genome size of 5 322 Mbp. Chickpeas and their new varieties are mainly cultivated in India, Pakistan and Iran. Its global production currently amounts to 13.1 million tons of seeds, obtained from an area of 13.2 million hectares, and the largest producers are India, Turkey and Pakistan. Worldwide chickpea seed yields range from 0.4 to 3.1 tonnes per hectare, depending on the agro-ecological conditions, the variety grown and the agrotechnology used. The yield potential of this species is estimated at approximately 6 tonnes of seeds per hectare. The main factor limiting the productivity of chickpeas is the underutilization of the breeding potential of cultivated varieties by agricultural producers due to the high sensitivity of this species to various types of abiotic and biotic stress. Chickpeas are thermosensitive, require strong sunlight during vegetation, have an undetermined growth rhythm, which makes it difficult to determine the optimal date for seed harvesting (uneven ripening of pods on the plant) and are characterised by a low harvest index. In order to satisfy the world’s needs for chickpea seeds, it is necessary to increase productivity 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.

In breeding and cultivation of chickpeas, two types are distinguished (based on the colour, shape and size of the seeds):

Desi: seeds are usually small, two times smaller than those of the kabuli chickpeas, with a thicker (11.5 % of the total weight of the seeds), irregularly shaped, rugged seed cover, light brown to black in colour. Seeds of a shade of brown, yellow, green and black are commonly found. The flowers are usually pink (rarely white) and the plants show varying degrees of anthocyanin pigmentation (some varieties’ flowers bloom in white and do not show anthocyanin pigmentation on the stem). The desi types take up 80–85 % of the total area under chickpea cultivation.

Kabuli: the seeds are usually large, have the shape of a ram's head and are characterised by thin (4.3–4.4 % of the total weight of the seeds), smooth seed cover that is white (low tannin content) or light cream in colour. The plants most often have white flowers and no anthocyanin pigmentation in their vegetative tissues. Compared to the desi type, kabuli seeds have a higher sucrose and lower fibre content. The kabuli varieties usually have large round seeds which, when cooked, remain firm and obtain a higher market price than the desi varieties. The kabuli varieties are a result of natural mutations and selections of the desi chickpeas.

The main objectives of chickpea breeding are as follows:

- cultivation of varieties with high yield potential adapted to the different agro-climatic conditions;
- shortening of the vegetation period and accelerating and increasing the uniformity of the ripening of pods and seeds;
- obtaining varieties with a shortened vegetation period, allowing them to be grown in succession within one year (vegetation season);
- increasing resistance to diseases such as ascochytosis, field bean rust, fusarium rot and root rot, the causes of which are, respectively: *Ascochyta* spp., *Uromyces viciae-fabae* (Pers.) J. Schrot., *Fusarium oxysporum* Schl. and *Fusarium solani* (Mart.) Sacc.;
- increasing resistance to pests such as the pea aphid (*Acyrthosiphon pisum* Harris), European corn borer (*Ostrinia nubilalis* Hübner), adzuki bean weevil (*Callosobruchus chinensis* L.);
- increasing tolerance to drought, air temperature fluctuations and soil salinity;
- identification of a stable form of male sterility, in order to breed heterozygous varieties.

5. INTEGRATED PROTECTION AGAINST PESTS

5. 1. Reducing the occurrence of weeds

Chickpea plantations may be infested by several or even more than a dozen species of weeds, both monocotyledons and dicotyledons. Their competitive effect on chickpea plants begins as early as at the time of seed germination, and very clearly intensifies during the development phase of 1–3 leaves formation. It decreases at the time of covering the inter-rows by chickpea plants.

In the cultivation of this species, the most effective method for reducing the size of weed infestation is the combination of agronomic treatments with appropriately selected herbicides (integrated method). In the protection of chickpea plantations, herbicides should be regarded as complementary to previously, properly carried out agronomic and maintenance treatments and not as the sole remedy (Dobrzański 2009, Dobrzański and Adamczewski 2009, Jemiołkowska et al. 2017).

5.1.1. The most important weed species

The most dangerous monocotyledon, annual, so-called thermophilic weeds include mainly: barnyard grass, yellow foxtail, and green foxtail, with hairy crabgrass sometimes occurring locally. Dicotyledon annual weeds occurring before or during the emergence of chickpeas, capable of threatening plantations, include: goosefoot, pansies, geraniums (e.g. small-flowered crane's-bill), wild camomile (e.g. field chamomile, common chamomile, false mayweed), red-root pigweed, potato weed, or dead-nettle (e.g. purple) (Paradowski 2013, Czubiński and Paradowski 2018).

Barnyard grass is an annual, spring, thermophilic species belonging to the *Poaceae* family, reaching a height of up to 90 cm (average 30–60 cm) (Figure 2). The period of its intense emergence occurs from the spring to the beginning of summer (from May to July), and it blooms from July to September, producing from 200 to 1 000 seeds, whose viability in the soil ranges from 3 to 7 years. This species is considered a common weed of most spring thermophilic crop species. It germinates en masse when the soil warms up to the temperature of about 10–15 °C. Barnyard grass is an indicator species of warm, rapidly heating soils rich in nitrogen, which the weed absorbs in very large quantities. The economic damage threshold of this species has not been defined for chickpeas, however, it is assumed to be around 3–6 plants per 1 m^2.

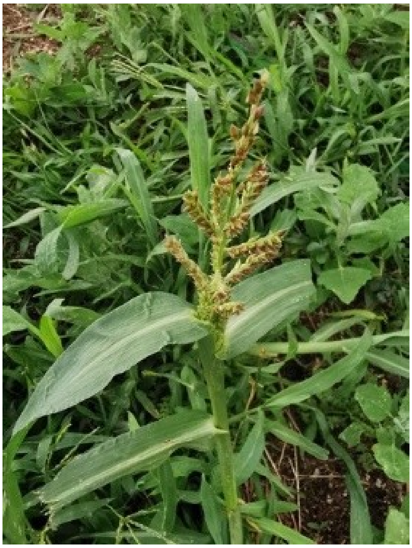


Figure 2. Barnyard grass (*Echinochloa crus-galli*)

Yellow foxtail is an annual, spring, thermophilic species belonging to the *Poaceae* family. Its stem reaches a height of up to 130 cm (10–50 cm on average) (Figure 3). The period of its intense emergence occurs from late spring to autumn (from June to September); it blooms from July to September and produces from 400 to 800 seeds, whose viability in the soil ranges from 10 to 15 years. This species is considered to be problematic for most cultivated thermophilic spring crops. In addition, it occurs in large quantities on stubble fields, fallow lands and set-aside land. It is an extremely thermophilic species and it germinates only when the soil warms up to a temperature of about 15–20 °C. Blue trichinella is an indicator species for dry, very warm, quickly warming soils. The economic damage threshold of this species has not been determined for chickpeas, but for most crops it is 6 plants per 1 m^2.

Image 3. Yellow foxtail (*Setaria pumila)*

The white footgoose is an annual spring species belonging to the *Amaranthaceae* family. Its stem has a height of up to 150 cm (average 10–100 cm) (Figure 4). Seeds germinate in spring, early summer and autumn (April–October). It blooms from June to October and produces between 200 and even 20 000 seeds, whose viability in the soil ranges from 10 to 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 its seeds, which retain their germination capacity for a long time, it is a very dangerous weed for 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 highly competitive for all cultivated plants. It is a hyper-accumulator of macronutrients, mainly nitrogen and potassium. The economic damage threshold for this species has not been established for chickpeas, however, it is assumed that even 2 pieces per 1 m^2 represent a threat to this crop.

Figure 4. White goosefoot (*Chenopodium album*)

The field pansy is also an annual species, emerging in spring and winter. It belongs to the *Violaceae* family and reaches a height of up to 50 cm (5–35 cm on average) (Figure 5). The seeds emerge in spring and autumn (March–May to September–November). Flowering from April to November, it produces between 150 and 3000 seeds, whose viability in the soil ranges from 2 to 10 years. It is a very common weed that occurs on different types of soils. It infests all field crops, and it also appears on fallow lands and uncultivated land. This species is highly competitive in the initial period of crop development and overpopulates the stand, worsening its phytosanitary conditions. Field violet can be a vector for some fungal diseases (powdery mildew, downy mildew, small leaf blotch). The economic damage threshold for this weed has not been established for chickpeas, but for most crops it is 20–25 plants per 1 m^2.

Figure 5: Field pansy **(***Viola arvensis)*

The small-flowered crane’s-bill an annual, spring and winter species, sometimes biennial, belonging to the *Geraniaceae* family. Its stem reaches a height of up to 60 cm (10–50 cm) (Figure 6). The emergence period may take place in spring (April–May) and autumn (September–October). It blooms from May to October, producing from 200 to 400 seeds, the lifespan of which in the soil can be from 1 to 10 years. It is currently an increasingly common species that inhabits various types of soils (prefers sandy low-clay sites) rich in nitrogen and calcium. It is quite tolerant to the soil's pH, as it grows well in both acidic and neutral conditions (pH 5.5 to 7.0). It infests all agricultural and horticultural crops, and especially thrives among cereals, root crops, rapeseed, maize and legumes. It is dangerous in the initial period of the chickpea’s growth, because if not combated, in extreme cases it can inhibit the growth of the crop. The economic damage threshold for this species has not been determined so far, but the observations of the growers themselves show that 25–35 pieces per 1 m^2 can cause a significant reduction in chickpea yield.

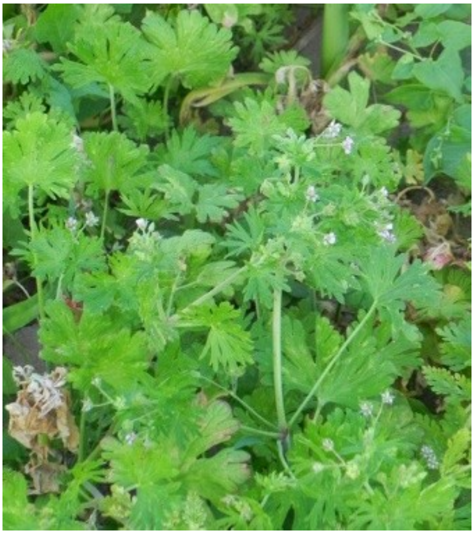


Figure 6. Small-flowered crane's-bill (*Geranium pusillum*)

False mayweed is an annual species, spring and winter, sometimes biennial, belonging to the *Asteraceae* family. It reaches a height of up to 80 cm (average 15–60 cm) (Figure 7). It emerges in spring and autumn (March–May to September–October). It blooms from May to October and produces from 5 000 to 300 000 seeds, the viability of which in the soil can range from 6 to 10 years. It is quite common especially on sandy and clay soils, especially humus- and nutrient-rich soils with low calcium content. It is a highly competitive species. It is most common in the main arable plant species. The economic damage threshold has not been defined for chickpeas, but in most agricultural crops it is between two and five plants per 1 m^2. At high density, it strongly shades the crop, causing it to lodge. Sometimes it may even inhibit the growth of the cultivated plant. In addition, it very often causes difficulties during harvesting.

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

Purple dead-nettle is an annual species, spring and winter, belonging to the *Lamiaceae* family. It grows to the height of 40 cm (10–30 cm on average) (Figure 8). The emerging period falls in spring (March–May) and autumn (September–November). It blooms from April to October, and under favourable conditions throughout the year. It produces from 60 to 4 500 seeds, whose viability in the soil can range from 8 to 30 years. It is a common species of weed, occurring mainly on clay and sandy-clay soils rich in humus and nutrients. It infests all agricultural crops (mainly cereals, rapeseed, potatoes, maize, legumes) and horticultural and fruit crops. In addition, it is very often found on baulks, fallow lands and set-aside land. It is a weed with high competitive strength in the initial period of chickpea vegetation. The economic damage threshold of this species for chickpeas has not been determined, but it is assumed that 10 to 15 plants of this species per 1 m^2 could pose a real threat to chickpeas. In addition, purple dead-nettle is an intermediate host for the red spider mite, which poses a big problem for growers of vegetables, berries, orchards and hops. In addition, this species also provides an alternative host to the soybean eelworm, which causes significant damage to the cultivation of soy and legumes.

Figure 8: Purple dead-nettle *Lamium purpureum*

Creeping thistle is a perennial species, sometimes biennial. It belongs to the *Asteraceae* family and its stem can be up to 180 cm (40–150 cm) in height (Figure 9). It emerges in the autumn (September–October) and spring (March–May). It blooms from July to October, producing from 3 000 to 40 000 seeds, the viability of which in the soil can be from 5 to 20 years. It is a species that can reproduce in two ways: generatively (seeds — mainly in spring) and vegetatively (from root to root, throughout the growing season). It is categorised as a very difficult weed and is present in all arable crops, as well as on grasslands and stubble fields. It grows on all types of soils, preferably airy, nutrient-rich soils. Its harmfulness results from the very intensive absorption of nutrients (mainly nitrogen, potassium and calcium) from the soil. Moreover, it is a very competitive species for cultivated plant species. Its economic damage threshold for most agricultural crops ranges from 0.5 to 1–2 plants per 1 m^2. At a high density, it can inhibit the growth of the arable crop, and it also makes it difficult to harvest chickpeas mechanically.


Figure 9. Creeping thistle (*Cirsium arvense*)

Red-root amaranth, like many others species, is an annual, spring, thermophilic species, belonging to the *Amaranthaceae* family. Its stem reaches a height of up to 150 cm (20–90 cm) (Figure 10). Seeds germinate in spring and early summer (May–June/July). It blooms from July to October and produces from 1 000 to 5 000 seeds, the viability of which in the soil can range from 10 to 40 years. It is most commonly found in humus-rich, fertile, nitrogen-rich soils among maize, beet, potato, sunflower and beetroot crops. It can also be found in gardens, on fallow lands and uncultivated land (but only for the first few years; then it disappears on its own). It is a nitrophilic and heliophyte species. In addition, it competes very strongly with the cultivated plant for water, nutrients and living space. When occurring in large adjacent quantities, it can have a very strong competitive impact, even inhibiting the agricultural plant from growing. Due to its size, it causes great difficulties when harvesting chickpeas. The economic damage threshold for this species has not been clearly defined, but it is assumed that as few as 1–2 plants per 1 m^2 can constitute a significant competition for chickpea plants.

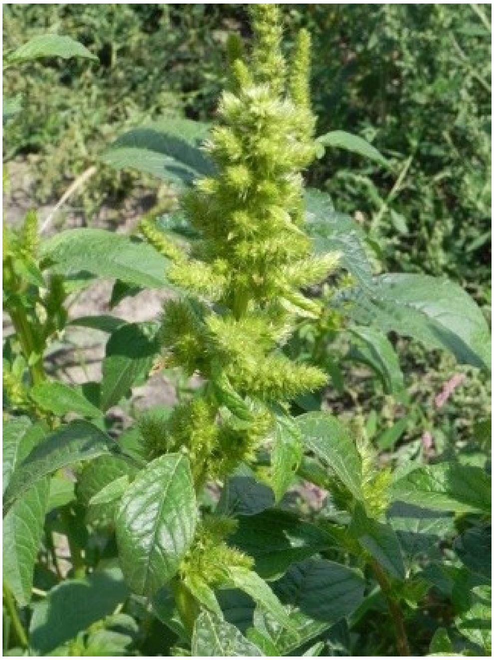


Figure 10: Red-root amaranth (*Amaranthus retroflexus*)

Potato weed is an annual, spring, thermophilic species belonging to the Asteraceae family. It reaches a height of up to 80 cm (average 10–40 cm) (Figure 11). It emerges in spring, summer and early autumn (May–September/October). It blooms from May to October, and produces from 5 000 to 300 000 seeds, the viability of which in the soil can range from two to five years. The species grows best in warm, ventilated, sandy-clay, humus- and nitrogen-rich soils. This weed is mainly found on the plantations of maize, potato, beetroot, sunflower, buckwheat and legumes. It can also occur on stubble lands and among vegetable plants. The high harmfulness of this species is mainly due to the possibility of producing several generations (two to three but sometimes as many as four) in one growing season (its full development only takes four to six weeks). The stems have the ability to self-root after contact with moist soil. Seeds in the soil only germinate from a depth of up to 2 cm (they practically do not germinate from the deeper layers of the soil), which is why agrotechnology is so important in its combating. This species is an excellent air temperature detector (spring or autumn frosts) because its leaves die off already at 0 °C. Moreover, this weed very intensely takes up nitrogen from the soil, which reduces its availability for the cultivated plant. The economic damage threshold for this species has not yet been developed for chickpeas, but it is assumed that 5 to 10 plants per 1 m^2 may already represent significant competition for the cultivated plants.

Figure 11. Potato weed (*Galinsoga parviflora*)

5.1.2. Non-chemical methods for regulating weed

Preventive measures are very important in the non-chemical reduction of weed infestation on chickpeas plantations. It is very important to choose the right place for cultivation (good structure of the soil), where few species of weeds that represent a low competition factor occur. It is equally important to use good quality seeds for sowing that have a high germination capacity and energy. It is also important to rotate the crops and to carry out pre-sowing soil cultivation with care, as well as to apply appropriate treatments after the emergence, but before the overgrowth of the inter-rows. Mechanical weed control in chickpea cultivation may be performed during the preparation of the planting site and after the chickpea plants emerge (Dobrzański and Adamczewski 2009, Zbytek 2009).

Due to the relatively late sowing date of chickpeas (usually the last third of April to the second third of May), mechanical weed control may be divided into two phases:

- First stage (before sowing chickpeas): mechanical control of emerging weeds using harrowing twice or thrice (depending on the moisture conditions of the soil) or shallow surface cultivation using a pre-sowing cultivation unit. These treatments, carried out in optimal soil moisture conditions, stimulate weed seeds to germinate, which are then effectively destroyed in subsequent treatment runs.
- Second stage (after chickpea emergence): mechanical weeding can be carried out with weeding in the inter-rows (this applies in particular to plantations with a wider row spacing, e.g. 40 cm), performing this treatment twice, i.e. at the 2–3 leaf stage of the chickpea plants' forming (BBCH 12–13), and the next treatment should be repeated after about 10–14 days, i.e. when the inter-rows begin to become overgrown (BBCH 39), but not later than in the phase of chickpea plants' formation of flower buds (BBCH 50).

5.1.3. Chemical methods of weed infestation control

The range of herbicide active substances recommended to protect chickpea plantations from weeds is limited.

Before emergence, only dicotyledon weeds can be effectively controlled, provided that there is an appropriate moisture content in the top layer of the soil. On the other hand, only graminicides, i.e. herbicides limiting only monocotyledon weeds, can be used in the post-emergence period (i.e. foliar application).

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 plant protection product search engine provides help in the selection of pesticide ( ). Current information on plant protection products use is available on the Ministry of Agriculture and Rural Development website at:

The list of plant protection products authorised under integrated production is available on the Online Pest Signalling Platform at:

5.2. Reduction of fungal diseases

5. 2. 1. The most important chickpea diseases

Under integrated cultivation of chickpeas, non-chemical methods always take priority in reducing diseases, and mainly agronomic and breeding methods are used. The chemical method may also be used where necessary. Chickpeas can be infected by one or several pathogens at the same time. The most economically significant chickpea diseases include verticillium wilt, rust, fusarium rot, root and stem base die-back (Table 14), and their occurrence worsens the quality and quantity of the harvested seeds (Kirk et al. 2008, Kryczyński and Weber 2010, Kryczyński and Weber 2011).

Table 14. Economic significance of selected chickpea pathogens in Poland

Disease	Pathogen(s)	Significance
Damping off	many fungi – *Thielaviopsis basicola*., *Fusarium* spp., *Rhizoctonia sp*.	++
Chickpea rust	*Uromyces ciceris-arietini*	+
Verticillium wilt	*Verticillium albo-atrum*	+
Fusarium rot	*Fusarium* spp.	+
Shoot and root blight	*Macrophomina phaseolina*	+

+ — small; ++ — medium

Under integrated plant production, information on the sources of primary and secondary infections, i.e. where the pathogen lives and how diseases are transmitted during chickpea vegetation, is particularly useful (Table 15).

Correct diagnosis and containment of diseases are one of the most important elements of integrated plant production.

Table 15. Main sources of disease infection and conditions conducive to the development of chickpea pathogens*

Disease	Sources of infection	Conditions conducive to development	
		temperature	soil and air humidity
Damping off	soil, post-harvest residues	5–15 °C	damp, cold soil, high air humidity

Shoot and root blight	fungi structures in the soil	15–20 °C	high temperature, rainy weather
Fusarium rot	post-harvest residues, spores spread by the wind	18–22 °C	warm, high humidity of the air
Verticillium wilt	microsclerotia	18–22 °C	low humidity, light soil
Chickpea rust	underground parts of plants, post-harvest	12–18 °C	high humidity of the air

* Drawn up by the authors based on: Fiedorow et al. 2008, Kryczyński and Weber 2010, Kryczyński and Weber 2011

The principles of integrated plant protection must be applied in the integrated production of chickpeas. In the Regulation of the Minister for Agriculture and Rural Development of 18 April 2013 on requirements for integrated plant protection, Section 2 on taking measures and methods of plant protection against harmful organisms refers to preventive monitoring of the occurrence of these organisms and taking into account current knowledge in the field of plant protection against pests. Where justified, taking into account, inter alia, recommendations from research studies making it possible to determine the optimal timing for the performance of chemical plant protection treatments, where such treatments are developed in particular on the basis of meteorological data and knowledge of the biology of harmful organisms. Therefore, in addition to knowing the sources of infection and the conditions conducive to the occurrence of a given disease, it is helpful to know the symptoms caused by pathogenic organisms when determining the disease on a chickpea plantation (Table 16). This will allow to identify the disease correctly, and when fungicide treatment is required, for an appropriate choice of treatment.

Table 16. Diagnostic features of selected chickpea diseases

Disease	Diagnostic features
Damping off	It threatens emerging chickpeas, inhibits the growth of seedlings and plants in their initial stages of growth. Yellowing, wilting and die-back of emergent plants. Blackening and rotting of the root system. Plants can be easily removed from the soil.
Fusarium rot	Plants' growth is inhibited. In the initial phase of flowering until the pod formation stage, plants lose turgidity and wither; in addition, their leaves turn yellow and die back.
Verticillium wilt	The plants wilt in the flowering phase. This process can be accelerated by water scarcity. A brown smudge is visible on the stem of a diseased plant running from its base.
Chickpea rust	Oval chloroses appear on the leaves, followed by light brown uredinium containing uredospores — propagative spores responsible for the spread of the disease.

5.2.2. Chemical protection methods

To control the disease pathogens under integrated production and protection, all non-chemical methods are used in the first instance. In justified cases, when these methods prove insufficiently effective, chemical methods of fighting pathogens are used. The use of non-chemical methods is of preventive nature. They should be used to combat plant pathogens in chickpea cultivation and the producer may use breeding, biological and agrotechnical methods (Mrówczyński 2013).

5.2.2.1. Breeding method

The effectiveness of agronomic treatments depends to a large extent on the quality of seeds used for sowing, which is one of the basic production factors. Healthy, good-quality seeds ensure healthy plant growth and development and a high yield from the beginning of the growing season. Cultivated varieties differ in their susceptibility to infestation by pathogens.

5.2.2.2. Agronomic method

The agronomic method consists of limiting the presence of disease pathogens primarily through the correct and timely implementation of all agronomic procedures in chickpea cultivation. These actions, in addition to sowing healthy and good-quality seeds, are the only methods used in cultivating chickpeas to reduce the occurrence of pathogenic fungi. It is therefore important to combine these two methods in order to minimise the impact of errors made during the preparation of soil for sowing and during the plantation management. The main goal is to prepare the soil in a way that will provide optimal conditions for crop emergence. Rapid emergence and nutrient availability increase plant resistance to infestation by soil and airborne pathogens. Using this method facilitates reducing chickpea infestation by a number of pathogens.

From an agronomic point of view, the factors limiting and, in some cases, eliminating the presence of pests in chickpeas may include:

- proper crop rotation;
- compliance with the timing of agronomic treatments and their careful implementation;
- appropriate fertilisation with organic, natural and mineral fertilisers;
- optimal time and depth of sowing and plant density;
- mechanical treatments;
- timely harvest.

All the above treatments affect the correct emergence, growth and development of plants. The timely harvest of chickpeas may have an impact on the quality of the harvested seeds. The period between the ripening of the seeds and harvest should be reasonably short in order to minimise losses resulting from the development of diseases and the possibility for fungi to populate the seeds. Seedling blight (damping off) is a disease that threatens emergent chickpeas.

5.2.3. Chemical methods of protection

One of the objectives of the introduction of integrated plant production is to ensure the safety of crop consumers. Chemical plant protection products should be used in such a way as to minimise the risk to organisms present in agrocenosis. Therefore, a product classified as toxic for humans may not be used under integrated production. **Fungicides should be used in accordance with the current list of products recommended for growing chickpeas under integrated production.**

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 (). Current information on plant protection products use is available on the Ministry of Agriculture and Rural Development website at:

The list of plant protection products authorised for IP is available on the Online Pest Signalling Platform at:

5. 3. Reducing the occurrence of pests

5.3.1.The most important chickpea pests

Legume plants may be damaged by many species of pests. Chickpeas are not particularly susceptible to pests, mainly due to their small cultivation area. Furthermore, when pests occur, they rarely cause losses of economic significance. However, pests typical for the cultivation of this group of plants may appear on plantations (Hołubowicz-Kliza et al. 2018, Tratwal et al. 2018) (Table 17).

The species typically present on chickpea plantations include pea leaf weevil, Sitona sulcifrons, Sitona humeralis, Sitona griseus and Sitona crinitus. There are beetles of the Curculionidae family, 4–8 mm long. They appear on plantations as one of the first pests. What poses the biggest threat to legume plants is the damage to young emerging plants caused by beetles during the spring. The greatest losses occur during the seed germination and emergence phase up to the six-leaf stage, especially under drought and low temperature conditions. They chew into leaves, leaving characteristic notches (serrated edges). Their foraging reduces the assimilation surface area of plants and increases the susceptibility of plants to diseases. Older plants usually become less damaged and are more resistant to the foraging of beetles, and can compensate for the damage as they grow and develop. The larvae damage the root hair and nodules in which bacteria fixing free nitrogen from the air develop. Damaged plants limit the assimilation area, which in the final phase causes a significant reduction in seed yield.

Table 17**.** The main pest species found in chickpea crops

Pest	**Significance**
Lygus (*Lygus* spp.)	(++)
Lucerne bug (*Adelphocoris lineolatus* Goeze)	(++)
Weevils (*Sitona* spp., *Charagmus* spp.)	(++)
Cutworms (*Agrotis* spp.), grubs (Scarabaeidae)	(++)
Thrips (*Thysanoptera*)	(+)
Whiteflies (Aleyrodidae)	(+)
Aphids (Aphididae)	(+)
Leafhoppers (Cicadellidae)	(+)
Pea moths (*Laspeyresia nigricana*)	(+)
Red spider mites (*Tetranychus urticae*)	(+)
Leaf miners (*Phytomyza* spp.)	(+)
Chalcid wasps (*Bruchophagus* spp.)	(+)
Root flies (*Delia* spp.)	(+)
Bean weevils (*Bruchidius* spp.)	(+)
Nematodes (Nematoda)	(+)
Gastropods (Mollusca)	(+)

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

Aphids — mainly of beetroot, lucerne and locusts, and peas. These pests suck juices out of the tissues, causing fragments of and even entire plants to die back. At the feeding sites, as a result of plant weakening, a secondary infestation by bacterial or fungal pathogens may occur. Aphids can also transmit viruses.

Leafhoppers, whiteflies and red spider mites appearing on crops are characterised by a similar spectrum of harmfulness**,** especially in dry and hot years.

On chickpeas plants, **true bugs** also occur, sucking sap from plant tissues. Locally, quite a large number of **lygus** and **lucerne bug** may occur, feeding mainly on leaves, shoots and flowers. By sucking the sap, true bugs (both adults and larvae) cause deformation and drying of tissue fragments and, in extreme cases, dying back of entire plants. Weakened plants are more sensitive to adverse climatic and soil conditions, and as a result of mechanical tissue damage, are more 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 vast infestation with 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 the **pea moth** occur from May to July. The caterpillars feed inside the pods, but they can also feed on leaves and flowers. Higher temperatures and dry, windless weather are conducive to the development of the moth. During the seed harvest period, moist conditions cause softening of pods and seeds, which makes it easier for caterpillars to drill inside and facilitates their further development.

Turnip maggot larvae belonging to the Anthomyiidae family attack emerging plants. As a result of damage to seeds, cotyledons and apical meristems, emerging plants blacken and die back or do not germinate. Egg laying by the maggot is facilitated by simplification of crop rotation and cultivation.

Local damage may be caused by **nematodes,** especially on humus-rich and moist soils. Invasive larvae overwinter in the plant material, therefore it is important to carefully remove the post-harvest residues.

Local losses may also be caused by **gastropods** and **leaf miners**. The larvae of the miners, feeding in the leaves, limit their assimilation surface.

For several years there an increase has been observed in the risk posed by **soil pests**, mainly **cutworms (butterfly caterpillars of the Noctuidae family)**, **wireworms** and **grubs**. With a strong infestation of the plantation by soil pests, the formation of bald patches on the sown areas is observed. Cutworms are gaining particular importance and their occurrence is facilitated by simplifications in cultivation technology, the close proximity of legumes, non-removal of post-harvest residues, the absence of or late winter ploughing, and the warming of the climate. 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 simplified crop rotation along with progressing climate warming create conditions conducive to changes in pest development, as well as to the mass occurrence of species that previously had no economic impact. The consequence of foraging pests is not only the reduction of green mass, but also their feeding on pods, which reduces the germination capacity of seeds and their commercial value. Integrated plant protection and production focuses on prevention measures, allowing intervention as a last resort. Therefore, constant, systematic observation of plants against the appearance and occurrence of pests is necessary. The most effective method is the direct monitoring of plants in search of damage or infestation by pests. Complementary methods should also be used, such as yellow vessels or sticky boards (to monitor for the infestation by aphids). It is also important to be able to recognize particular pest species, know its biology and potential dates of appearance on the plantation (Figure 12).

<table>
<tr><td></td><td></td><td></td><td></td><td colspan="2">PEA MOTHS</td><td></td><td></td></tr>
<tr><td colspan="6">SITONA WEEVILS</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="4">APHIDS, LEAFHOPPERS, WHITEFLIES</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="3">THRIPS</td><td></td><td></td></tr>
<tr><td colspan="2">CUTWORMS</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">ROOT FLIES</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">WHITE GRUBS, WIREWORMS</td><td></td></tr>
<tr><td colspan="3">GASTROPODS</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8">NEMATODES</td></tr>
<tr><td>Emergence (BBCH 00–09)</td><td>Leaf development (BBCH 10–19)</td><td>Development of lateral shoots (BBCH</td><td>Main shoot growth (BBCH 30–39)</td><td>Flower development (BBCH 50–59)</td><td>Blossoming (BBCH 60–69)</td><td>Development of pods (BBCH 71–79)</td><td>Ripening of seeds (BBCH 80–89)</td></tr>
</table>

Figure 12. Potential dates for the occurrence of the main pests during chickpea vegetation

5.3.2. Non-chemical pest control methods

One of the basic principles of integrated pest management is applying preventive measures, based primarily on the appropriate agronomic methods, which ensures proper growth and development, especially in the initial stages of growth, when plants are extremely rone to being attacked by individual pest species. Correct protection of chickpeas should be based on a wide range of agronomic methods, as proper compliance with the basic agronomic recommendations is a key element of the pest management programme (Mrówczyński 2013,Pruszyński and Wolny 2009, Pruszyński et al. 2012, Pruszyński 2016) (Table 18).

Table 18. Non-chemical methods of reducing the abundance of chickpea pests

Pest	Methods and measures of protection
Lygus pratensis Lucerne bug	proper crop rotation, ploughing, spatial isolation from other legumes, weed control
Thrips	proper crop rotation, early sowing, spatial isolation from other legumes, sustainable fertilisation, weed control, deep autumn ploughing
Pea aphid Leafhoppers Whiteflies	early sowing, sustainable fertilisation (mainly N), spatial isolation from other legumes, including perennial species
Bean weevils	harvesting as early as possible, deep autumn ploughing
Pea moths	proper crop rotation, possibly early sowing, spatial isolation from other legumes, including those from the previous year
Red spider mites	containment of weed infestation and limiting plant residues, balanced fertilisation, spatial isolation, mainly away from root and orchard crops
Leaf miners	ploughing, sustainable fertilisation, weed control
Wireworms, grubs, cutworms	proper crop rotation, ploughing, harrowing, weed control, higher seed sowing rate, deep autumn ploughing
Root flies	early sowing, higher seed sowing rate, weed control, careful manure ploughing
Gastropods	proper crop rotation, ploughing, harrowing, early and deeper sowing, weed control, crop residue fragmentation, deep autumn ploughing
Nematodes	removal of plant residues

In the cultivation of chickpeas, as with other legume plant species, proper crop rotation is very important. Many pests overwinter in the top layer of the soil or leftover plant residues. For the same reason, it is recommended to apply spatial isolation from other legume species (also cultivated in the previous year) and other host plants of individual pests, e.g. perennial legumes in the case of pea aphids or Lygus bugs. Spatial isolation also helps make certain pests need to fly over longer distances. In pest control, beneficial organisms living in agrocenosis are also important, forming so-called natural environmental resistance (Boczek and Lipa 1978, Ciepielewska 1991, Fiedler 2007, Ignatowicz and Olszak 1998, Pruszyński 2007, Sosnowska and Fiedler 2013).

Measures to limit the potential damage caused by individual pest species can already be undertaken during seed sowing. Faster initial vegetation of plants makes it possible to get ahead of the period of greatest danger from all pests, especially those that pose threat for emerging plants. Faster growth allows for a stronger competition for weeds, which may constitute a food base for certain pests. Proper planting is also important; too dense sowing makes it easier for pests to spread, while sowing too sparsely is conducive to weed infestation. 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. Harvesting too late creates the risk of greater losses, especially qualitative ones caused by insects that can damage the pods.

Following the harvest, it is important to perform post-harvest cultivation treatments, aimed at precise fragmentation of post-harvest residues (where certain pests overwinter and develop), to prevent weed seeds, including the perennial ones, from germinating. In autumn, it is necessary to perform a deep ploughing, which also fulfils a phytosanitary objective. A thick layer of soil covers the overwintering 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. The treatment also destroys many soil pests.

5.3.3.Chemical pest control methods

Pesticides should be used in accordance with the current list of integrated production plant protection products recommended for use in chickpeas. The list of plant protection products authorised for IP is available on the Online Pest Signalling Platform at:

Messages published on the Online Pest Signalling Platform () may be helpful in the systematic monitoring of pests. Before applying a product, it is necessary to consult its use label, which provides information on the scope of pesticide use in each crop. 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: .

5.3.4. Methods for determining abundance and damage thresholds

Monitoring for the occurrence of pests on 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 monitor the field systematically, from emergence to the beginning of ripening of the plants, at least once a week during the occurence period of soil pests, weevils, aphids and pea moths, 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. Depending on the shape of the field, observation should be carried out on the outer limits of the field and on two diagonal lines dividing the plantation. Depending on the pest species, the average number of pests per 1 m^2 or on 100 randomly selected plants should be checked. Such observations should be carried out in several places on the plantation. Other methods are also useful, such as sweep-netting or sticky boards. The assessment of the presence of soil pests is carried out in several locations by sieving the soil from excavated wells of 25x25 cm and 30 cm of depth.

Monitoring should be carried out both in order to determine the time of infestation and number of harmful insects on the plantation, and after the treatment to check the effectiveness of pest control. In case of unsatisfactory effectiveness, resistance to treatment (Malinowski 2003, Węgorek et al. 2013) or prolonged infestations of harmful insects, it allows for a quick reaction and, if needed, a repeat treatment. Proper inspection requires knowledge of pest morphology and 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 chickpeas, specific damage thresholds have not been determined.

However, there are general rules and time-lines for the observation of certain species of legume pests (Table 19).

Table **19.** Rules for pest monitoring in legume crops.

Pest	Principle of observation	Date of observation (developmental
Sitona weevils	crop inspection for damage — serrated leaf edges	leaf emergence and development (BBCH 10–19)
Aphids	presence of aphid colonies on all vegetative organs	growth and flowering (BBCH 30–69)
Pea moths	observation of the presence of caterpillars and damage they cause; pheromone traps	inflorescence development and flowering (BBCH
Soil pests	inspection of crops for damage to roots, germs, cotyledons (characteristic bald patches on the sown area)	emergence and leaf development (BBCH 09–15)
European tarnished plant bug Lucerne bug	inspection of crops for imago and larvae and damage to leaves, flowers and pods	shoot development to pod maturation (BBCH 21–75)

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

Integrated plant protection programmes require considerable knowledge and experience from the farmer in terms of pest identification, development stage assessment, habitation and methods of pest reduction and elimination. Information on pest biology, data from previous years on the occurrence of a pest in a given area combined with knowledge of loss reduction measures can help in deciding on a treatment. The benefits of knowledge about modern plant protection methods have not only an economic dimension, but are also an expression of care for a healthy environment (Doruchowski and Hołownicki 2009, Dominik and Schönthaler 2012, Häni et al. 1998).

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 the necessary minimum.

The Online Pest Signalling Platform managed by the Institute of Plant Protection — National Research Institute and partner institutions contains, among other things, the results of monitoring of individual stages of pest growth in selected locations for the needs of short-term forecasting. ().

Currently, there are no damage thresholds determined for chickpeas. It is assumed that the chemical treatment should be carried out after the occurrence of pests on more than 5 % of the analysed plants, because the loss in yield in such a case would be significant and have an economic impact.

6. BIOLOGICAL METHODS IN INTEGRATED PLANT PRODUCTION

6.1. Biological methods

Biological methods consist in the use of such biological factors as viruses, bacteria, fungi, nematodes and entomophages (parasitic and predatory insects) to reduce populations of harmful organisms (pests, plant disease vectors and weeds) in fields and in covered plantations. Biological methods in most cases work slower than traditional chemical protection. This is influenced by a number of factors, including environmental conditions, but also the biology itself and the mechanism of action of a biological agent on the controlled 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 plan treatments correctly depending on the status of the plants in a particular area. Monitoring the pest outbreak, including historical knowledge of the phytosanitary status of the crop from previous seasons, allows for biological protection of chickpeas to be planned accordingly.

Pest population control in chickpea cultivation may be carried out with registered bioinsecticides containing, for example, bacteria of the *Bacillus* genus or fungi of the *Beauveria* genus.

When using microorganisms to control chickpea pests, please note that:

- they are sensitive to high temperatures and strong sunlight;
- the bacteria are best used when the first caterpillars/larvae of the pest appear, as the younger stages of the pest's development are more sensitive to insecticidal bacteria;
- insecticidal fungi in their first stage of action require temperatures of around 25 ^{o}C and high humidity to germinate and enter the insect;
- after eating the insecticidal bacteria, the caterpillars of the pest only die after 24–72 hours, during which time they can feed and look healthy;
- microorganisms are used with self-propelled or tractor field sprayers; such treatments should be carried out in the evening or early in the morning;
- chemical plant protection products must not be used after the use of biological agents 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 six months.

6.2. Rules for the use of biological plant protection products

Biological plant protection products must be used in accordance with the product label. The content of the label is the basis for achieving the effectiveness of the product. Its instructions must be strictly adhered to. The quality of the biopreparation is the responsibility of the manufacturer or 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 chemical plant protection products, but significantly reduce their populations, usually over a longer period of action.

It is important to remember that:

In the environment, biological factors, i.e. elements of the living environment, directly or indirectly affect the life of organisms, one example being the antagonistic effect of bacteria of the *Bacillus* and *Pseudomonas* genera on the insecticide fungus *Beauveria bassiana*, which should not be used together.

6.3. Conservation biological protection

Biological protection consists not only in the use of registered microbiological biopreparations. It is supported by conservation biological protection, which consists of human modification of the agricultural landscape to create suitable conditions for the development of beneficial organisms in the environment (Sosnowska 2018, Sosnowska 2022). Under favourable conditions, macroorganisms acting in the environment may reduce pest populations in chickpeas and thus support the action of biological agents.

Ladybugs, lacewings and flower flies feed on aphids, which contributes to the reduction of their abundance. Insecticidal fungi in the soil environment can reduce the overwintering stages of pests, such as the fungus *Metarhizium* spp. Insecticide fungi often cause epizootics (mass death) in aphid colonies. An important role is played by insecticidal nematodes, which destroy pests in the soil. The action of these biological factors in the environment can be supported by keeping baulks empty, planting trees in the field, sowing melliferous plants (buckwheat, phacelia, borage and others), sowing flower strips and applying appropriate agronomic methods. It should be noted that macroorganisms are not subject to registration in Poland.

In reducing chickpeas pests, it is also important to protect their natural enemies, which can reduce the populations of various pests in the environment. Beneficial organisms active in the environment include predatory beetles such as ground beetles, rove beetles and ladybirds; parasitic flies (e.g. tachinid flies) and Hymenoptera (e.g. aphid wasps and ichneumon wasps); predatory flies (e.g. flower flies and gall midges); predatory true bugs and lacewings; and many others that provide natural resistance in the environment (Tomalak 2008).

In the soil environment, under favourable conditions, various species of insecticidal fungi can act to reduce the abundance of grubs, for example: *Beauveria bassiana*, *B. brongniartii*, *Cordyceps fumosorosea*, *C. farinosa* and *Metarhizium anisopliae*. Aphids on leaves can be infected by insecticidal fungi of the *Entomophthoraceae* family. When temperatures and humidity are high, they often cause epizootics, i.e. mass die-back of chickpeas aphid colonies. 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 harmful pest populations. This can also be the case of certain amphibians, birds or mammals (Wiech 1997). The common toad feeds on a variety of foods, predominantly gastropods and insects, often the harmful types. One of the insectivorous mammals is the mole. It is a useful animal that feeds on white grubs and other insects found in the soil. The largest representative of insectivorous mammals is the hedgehog, which hunts at night, and its food consists in insects, gastropods and other animals. Birds that kill pests play a useful role in the environment, e.g. in spring and summer the great tit feeds on leaf-eating caterpillars and butterflies.

Predatory birds living near plantations are effective in controlling small mammals (rodents, hares). In order to help them scout for prey, a resting pole at least 3 m high should be placed per every 5 ha of the plantation along its edges.

<u>Activities that support the effectiveness of biological agents in the environment:</u>

- leaving dead furrows, thickets, shrubs and mid-field refuges that support the

development of beneficial insects and microorganisms that live there;
- forest surroundings are a refuge for beneficial insects and microorganisms (e.g. insecticidal fungi);
- sowing melliferous plants and creating flowering strips among crops;
- use of organic fertilisers;
- crop rotation;
- cultivation technologies, e.g. zero-tillage cultivation (higher soil moisture contributes to the effectiveness of insecticides);
- the use of selective chemical plant protection products.

Plant protection products, including biological agents, should be used in crops for which they are recommended and the information contained in the labelling of the product 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 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’.

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

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

- rational use of chemical plant protection products and making decisions based on the real risk to the crop from pests, assessed on an ongoing basis. One should consider abandoning treatments if pests do not occur in large numbers and are accompanied by the occurrence of beneficial species. In this group of activities, the limitation of the treatment area to treatments on the edges and in patches should be considered if the pest does not occur on the whole plantation. The use of tested mixtures of plant protection products and liquid fertilisers should be recommended as it reduces the number of entries into the field and mechanical damage to plants;
- protection of beneficial species by avoiding the use of insecticides with a broad spectrum of action and replacing them with selective agents;
- choosing the treatment time to prevent high mortality among beneficial insects;
- based on the studies, reducing doses and adding adjuvants;
- constant awareness that protecting natural enemies of pests also protects other beneficial species present in the field;
- leaving dead furrows and mid-field shelters as a habitat for many species of beneficial insects;
- reading the content of the label accompanying each plant protection product carefully 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 objects for pollinating insects should be placed within the cultivated area at a number of at least 1 per 5 ha.

7. APPROPRIATE TECHNIQUES FOR THE USE OF 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 Act,
  - soil contamination due to leakage or seepage of plant protection products into the soil profile,
  - penetration into sewage systems, excluding separate drain-free sewage systems equipped with a leak-proof sewage tank or equipment for their neutralisation.

The labels of plant protection products approved by the Minister for Agriculture and Rural Development contain information on the principles of safe storage. In accordance with the good practice principles, plant protection products should be stored in separate rooms (outside residential and livestock buildings). These rooms should be clearly 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 carrying out spraying treatments with the use of plant protection products, including sprayer operators, must be suitably qualified by a certificate of completion of training in the use of such products or advisory on plant protection products and integrated plant production, or another document attesting to holding a permission to carry out plant protection treatments. The sprayer operator must be equipped with appropriate protective clothing, as prescribed on the label and in the safety data sheet of the plant protection product. The basic equipment of protective clothing includes: a suit, suitable shoes, rubber gloves resistant to plant protection products, glasses to protect the eyes, a mask protecting the respiratory system and covering the mouth. Proper work organisation and available technical measures should be used at each stage of the handling of plant protection products, in accordance with the principles of **Good Plant Protection Practice.**

Devices and equipment for protective treatments

The sprayer or other equipment used for crop protection must be technically fit for use, ensure reliable operation and guarantee the safe use of plant protection products, liquid fertilisers or other agrochemicals. The sprayer must have undergone a technical inspection (with up-to-date certification) and be properly calibrated. The technical efficiency of the equipment is confirmed by the protocol of the testing carried out and by the control mark issued by an institution authorised to do so (sprayer inspection stations). Testing of new equipment must be carried out no later than five years after its acquisition and subsequent tests must be carried out at intervals of no more than three years. 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, fluid system and agitator. It is also advisable to carry out a preventive rinsing of the sprayer in order to remove mechanical impurities and possible residues after previously performed treatments.

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 adjustments of the sprayer make it possible to choose the optimal parameters of the treatment. In accordance with good plant protection practice in terms of the adjustment (calibration) process of the sprayer, the type and dimension of the sprayers and the working pressure should be determined, which ensure the application of the intended dose of liquid per hectare for the specified operating speed of the sprayer. The adjustment of the sprayer's operating parameters should be performed when changing the type of chemical agent (especially from herbicide to fungicide or insecticide), the dose of the sprayed liquid, as well as the setting of operating parameters (working pressure, field beam height). The adjustment of the sprayer should be carried out each time when important equipment and components of the sprayer (nozzles, pressure gauge, control device, repair of essential elements of the liquid system) are replaced, as well as in case of 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 subject matter publications.

Choice of plant protection product and dosage

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

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

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

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

Selection of spray liquid volume

In integrated production, the volume of spray ($l\ ha^{-1}$) should be selected based on available catalogues, training materials and handbooks or other subject matter publications. Determination of spray liquid volume should take into account factors such as the type of crop to be sprayed, the development stage of the plants, the density of the crop, the possibility to use different spraying techniques (type of treatment device, type and kind of spraying equipment), as well as the recommendations included in the label of the specific plant protection product. Contact-action agents require very good coverage of the plants being sprayed and generally require higher volumes of spray than systemic agents. In foliar feeding treatments and when combining the use of several chemicals, it is recommended to use increased volumes of spray liquid. With appropriate treatment equipment (e.g. air assisted 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 concerning their use are useful in the selection of suitable sprays for individual plant protection treatments. The selection of the sprayer for specific protective treatments should be preceded by familiarisation with its technical characteristics, and above all with the information on the type, size of the spray nozzle and the flow rate of the liquid.

Preparation of spray liquid

The intended volume of the liquid should be prepared immediately before the procedure to avoid undesirable physicochemical reactions. The sprayer agitator must be switched on at all times to protect the mixture from precipitation at the bottom of the tank. Before pouring the product into the tank, it is necessary to read the indications on the label as to the method of preparation of the spray liquid and the possibility of mixing the product with other preparations, adjuvants or fertilisers.

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

Sprayer filling:

- the sprayer must be filled on an impermeable and hardened surface (e.g. concrete slab), in a place where it is possible to prevent the spreading of spilled or leaked plant protection products;
- the measured quantity of crop protection product should be poured into the partially filled tank with the agitator switched on or in accordance with the instructions for use of the sprayer;
- empty plant protection product packaging must be rinsed three times, the contents poured into the spray tank, and the packaging preferably returned to the dealer;
- if possible, it is best to fill the sprayer on a special stand with a biologically active substrate;
- when filling the sprayer on a permeable surface, 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 disposed of using absorbent material (e.g. sawdust);
- contaminated absorbent material should be collected and deposited at a 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 agitator on. Other components are added to the prepared solution. It is recommended that they be pre-diluted before being poured into the sprayer tank. Start with an adjuvant that improves the compatibility of the components of the mixture, if used. Then plant protection products are added (in the correct order, according to the formulation), followed by water to the desired volume of the sprayer tank. In multiple-component mixtures with the use of two or more plant protection products, the order of their addition to the liquid should be followed according to the physical characteristics of the formulations. First, add preparations that form a suspension in water, then add agents that form emulsions, and finally, solutions. After adding all the components, fill the tank up with water to the required volume. Cold (taken up directly from a deep well), very hard or contaminated water should not be used for the treatment. Protective treatments may begin when the spray liquid is properly prepared.

7.3. Treatment conditions

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

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

Table 20 shows recommendations for optimal and limiting weather conditions during spray applications. The recommended air temperatures during treatments are conditioned by the type and mechanism of action of the plant protection product applied and such data are included in the label texts. For most preparations, optimal effectiveness is achieved at a temperature of 12–20 °C.

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

Table 20. Limit and optimal meteorological conditions for plant protection treatments

Parameter	**Limit values (extreme)**	**Optimal values (most favourable)**
Temperatures	1–25 °C during the treatment	12–20 °C during the
	up to 25 °C the day after the	20 °C the day after the
	no lower than 1 °C the following night	no lower than 1 °C the following night
Air humidity	40–95 %	75–95 %
Rainfall	less than 0.1 mm during the	no rainfall
	less than 2.0 mm within 3–6 hours of the treatment	
Wind speed	0.0–4.0 m/s	0.5–1.5 m/s

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

- at least 20 m from 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 those to be treated with plant protection products;
- in the case of tractor sprayers and self-propelled field sprayers, at least 1 m from reservoirs and watercourses and lands not used for agriculture, other than those to be treated with plant protection products.

It is important to bear in mind the obligation to comply with the labelling of plant protection products in the first place. On many labels, distances (buffer zones) from specific sites and facilities for the use of plant protection products are greater than those indicated above.

The spraying procedure is performed at a constant movement speed and working pressure, set during sprayer adjustment. Successive runs over the field should be made very precisely to avoid strips being left unsprayed and so that no overlapping of the sprayed liquid occurs in already sprayed areas.

7.4. Post-spraying procedure

At the end of each treatment cycle, the leftover spray liquid must be removed from the sprayer by spraying the spray liquid in the field or plantation where the treatment has been carried out or on the producer’s own unused agricultural area, away from drinking water intakes, and sewer wells. The sprayer must be washed thoroughly in the place intended for this purpose. **The remaining liquid must not be poured into the soil or into the sewage system or in any other place that prevents its collection or poses a risk of contamination of the soil and water**. **Washing and rinsing the tank and the liquid sprayer installation should be carried out at a safe distance (no less than 30 m) from wells, water intakes and reservoirs and watercourses.**

Procedure for rinsing the tank and liquid system

- Use the least necessary amount of water for rinsing (2–10 % of the volume of the tank or an amount that dilutes liquid remaining in the tank up to 10 times); it is recommended to rinse the liquid system with a small portion of water three times.
- Turn on the pump and rinse all the elements of the liquid system used during the procedure.
- Spray the rinsings on previously sprayed surface or, if it is not possible, use the residues according to the recommendations on the management of liquid residues.
- The residual liquid drained from the sprayer must be disposed of using technical equipment that ensures biodegradation of the active substances contained in plant protection products. Until neutralisation or disposal, liquid residues may be stored in a sealed, labelled and secured container earmarked for that purpose.

External sprayer washing

After the end of the working day, all equipment should be washed on the outside with water, as should its components that have contact with chemical agents. External washing of the sprayer should be carried out at a location that allows the washings to be directed into a closed collection system for contaminated residues or into a neutralisation/bioremediation system (e.g. Biobed, Phytobac, Vertibac station); if this is not possible, the sprayer should preferably be washed in the field. 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 efficiency of external washing. Recommended, biodegradable products should be used to increase the washing efficiency.

Recording of treatments

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

- the name 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.

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

8. PREPARATION FOR HARVESTING, HARVEST, STORAGE OF CROPS

Chickpeas are ready for harvest when the leaves begin to turn brown and dry, and some have already fallen. The stems, pods and seeds are then light yellow. The pods of the chickpeas are resistant to cracking, but when harvesting is delayed, the pods may fall and the stems break, resulting in seed losses. In addition, pods of this species ripen quite unevenly, which largely depends on the weather conditions during this period. In the case of harvesting with a harvester, the moisture content of the seeds should be between 15 and 18 %, so that the mechanical damage to the seeds is limited. Harvesting of seeds with a moisture content of less than 13 % increases the damage to the pods and the cracking of the seeds, which can not only increase losses but also reduce yield quality. The harvest date usually falls in September, but it can be delayed in case of rainfall.

The adaptation of the harvester to harvesting chickpeas consists in reducing the rotation speed of the threshing drum to 500–600 RPM, widening the gap between the drum and the threshing floor to the maximum setting, and setting high fan speed and openings. The top sieve should be set at 2.0–2.5 cm and the bottom one at 1.3–1.5 cm, and the sieves should be properly selected (Księżak i Podleśny 2002). During the adjustment, account should be taken, inter alia, of plant moisture, weed infestation, and lodging. If the weather is dry and sunny, the seeds may dry out (and break during harvesting). In such a case, they must be harvested early in the morning or at night, reducing the rotation of the drum to up to 450 RPM. The correct harvest and reduction of losses largely depends on the skills of the harvester operator. The final harvester settings should be determined after the test harvest has been performed at a distance of 50–100 m.

After threshing, the seeds need to be cleaned and dried to 13–14 % moisture. Seeds intended for sowing should be dried slowly and gradually. Therefore, in it is not allowed to reduce the moisture content of seeds in dryers by more than 3 % at a time, as they can become damaged. It should also be observed that the wetter the seeds are, the lower their drying temperature should be. Seeds containing 30 % water should be dried at a temperature not exceeding 30 °C. After reducing the moisture content of the seeds to 25 % and then to 20%, the air temperature may be raised to 35 °C and 45 °C, respectively. The drying of chickpea seeds intended for food purposes should not take place at too high a temperature, as this could lead to a deterioration in the bioavailability of certain nutrients. Seeds should be dried in a warehouse with unheated air or by frequent shovelling of a thinly spread layer.

9. DAMAGE TO CHICKPEA CROPS CAUSED BY WILD GAME

Wild game damage is damage caused to crops and agricultural products by wild boars, elks, deer, fallow deer and roe-deer, as well as during hunting.

Damage to agricultural crops caused by wild animals is a problem that remains unresolved and one causing many difficulties and dissatisfaction in terms of legal, procedural and, above all, methodological aspects related to the valuation of losses and determination of the amount of compensation to be paid to the farmer. Therefore, for many years an effort has been made to improve the legal and methodological arrangements for estimating losses in plantations and crops. However, the often changing legal aspects of estimation do not provide any concrete solutions that would allow for quick and objective action by hunting clubs or game breeding centres as well as the affected farmers (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). Due to the attractiveness of legume species as a feeding ground for wildlife, especially wild boars and birds (pigeons and the Corvidae), the issue of wild game damage to the crops of these species is very important. If the seeds have not been treated, they are at risk of being destroyed by birds several days after sowing. Crops with a small area (up to 0.5 ha) can be destroyed overnight, especially in areas located near forest complexes. In the event of complete destruction of the crop, estimators and representatives of agricultural chambers find it difficult is to record the potential yield in the protocol.

Legume species producing large seeds are very attractive for all types of birds and large wild game, especially for wild boars. The damage caused by wild game is very similar to that caused in maize plantations. 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 photographs. If only local damage occurs, the procedure is very simple. The measurement unit (MU) is 1 m^2, 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 the plant density on undamaged areas within the measurement units should take into account all factors affecting the plant density, such as pests, diseases and weather 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 areas, especially in the case of cultivation of species little known 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 regarding the amount of compensation), the estimators should seek advice from the Agricultural Advisory Centre.

10. RULES FOR KEEPING RECORDS AS PART OF INTEGRATED PRODUCTION

Cultivation of plants under the integrated plant production scheme is inextricably 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 such documents.

Model notebooks are included in the Annex to the Regulation of the Minister for Agriculture and Rural Development of 24 June 2013 on documenting activities related to integrated plant production (Journal of Laws of 2023, item 2501). The record-keeping rules will change on 1 January 2026 as a result of the application of the Implementing Regulation (EU) 2023/564.

Other documents that a producer using integrated plant production must possess or may encounter during the certification process include:

- the methodology of integrated plant production;
- the notification of accession to the integrated plant production scheme;
- the certificate of the registration number;
- the 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 the GDPR;
- lists of plant protection products for IP;
- inspection reports;
- mandatory and control lists;
- results of tests for residues of plant protection products and levels of nitrates, nitrites and heavy metals in agricultural crops;
- soil and leaf analyses results;
- certificates of completion of training;
- reports or proofs of purchase attesting to the technical fitness of the equipment for the application of plant protection products;
- purchase invoices for, among other things, plant protection products and fertilisers;
- application for the certificate;
- IP certificate.

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

The application form should be completed with information such as:

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

The application must also include the date and signature of the applicant. The declaration shall be accompanied by information on the species and varieties of plants to be grown under the IP system and the location and area of their cultivation.

A copy of the certificate of completion of training in integrated plant production or a copy of the certificate or copies of other documents attesting to the qualification must also be attached to the application.

During cultivation, the agricultural producer is obliged to keep records of activities related to integrated plant production in the IP Notebook on an ongoing basis. When applying for the certification for more than one plant species, IP Notebooks must be kept individually for each species.

The Notebook should be filled out according to the following outline.

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

Inventory of fields (…) under the integrated plant production scheme — all cultivated varieties declared for the IP certification to be recorded in the field inventory table.

Field plan with biodiversity-increasing elements — graphical map of the holding and its immediate surroundings with the correct proportions of the various elements. The holding plan uses the same markings as those used in the field inventory.

General information, sprayers, operators — the year in which production according to the principles of Integrated Plant Production started. Then, the tables must be filled in. The bullet points should be filled in with appropriate entries and the information confirmed by ticking the relevant boxes (□). The 'Sprayers' table should be filled in with the required data and the information confirmed by ticking the relevant boxes (□). Last names of all sprayer operators carrying out plant protection treatments must be listed in the 'Sprayer operator(s)' table. It is absolutely necessary to indicate that the training in the use of plant protection products (or other qualification) is up to date, including the date of completion. In the 'Sprayers' and 'Sprayer operator(s)' tables, all devices and persons performing treatments, including those performed by a service provider, must be listed.

Purchased plant protection products — the purchased plant protection products (trade name and quantity) intended to protect the crop for which the Notebook is kept must be recorded in the table. **Monitoring tools, e.g. colour stickers, pheromone traps** — in this table the colour stickers, pheromone traps and other similar measures used must be recorded with an indication of the pests which these tools were intended to monitor.

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

Seed/seeds — table to be completed with information on the seed(s) purchased for sowing (variety name, category, degree of certification, quantity, plant passport, seed label), if applicable, and a proof of purchase (invoice).

Sowing — the table is intended to record the amount of seeds used on each field. The dates of the activities carried out should also be recorded. For this purpose, tick the relevant boxes (□) to confirm the information on soil testing/assessment for pests which would exclude the field from IP cultivation.

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

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

Harvest — in this table, record the yields harvested from each field.

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

Other mandatory requirements for the protection of plants against pests according to the requirements of the method — a page in the Notebook containing space for IP producer's comments concerning the requirements for pest management set out in the integrated plant production methodologies.

Information on the cleaning of machinery, devices and equipment used in production, according to the requirements of the integrated production methodology — Notebook page intended for the IP producer's information relating to the cleaning of machinery, devices and equipment used in the production, which is required under the integrated production methodology.

The Notebook also contains space for comments and own notes, and a list of appendices. Obtaining the certificate It is possible for an agricultural producer to obtain an IP certificate by applying to a certification body. Relevant application forms are available from the certification bodies. Along with the completed application for a certificate attesting to the application of integrated plant production, the plant producer provides the certifying body with a declaration that the cultivation has been carried out in accordance with the requirements of integrated plant production, and information on the species and varieties of plants grown in line with the requirements of integrated plant production, the area of their cultivation and the yield size.

11. LIST OF MANDATORY PROCEDURES AND TREATMENTS IN INTEGRATED PRODUCTION OF CHICKPEAS

Mandatory requirements (100 % compliance, i.e. 11 points)			
Item	**Checkpoints**	**YES/ NO**	**Comment**
1.	Use of appropriate crop rotation (20–25 % share of chickpeas) indicated in the methodology	□/□	
2.	Performing mechanical weeding treatments before sowing (Chapter 3.3.4).	□/□	
3.	Sowing within the period appropriate for the region concerned, in line with the appropriate standard and parameters of sowing (Chapter 3.3.6)	□/□	
4.	Use of macro- and micronutrient fertilisation at appropriate times and doses depending on the soil type and pH, preceded by nutrient balance analysis supported by relevant documents (Chapter 3.3.5).	□/□	
5.	The use of agronomic methods as the first instance in weed control and, in the case of chemical control, the correct application of herbicide at the appropriate dose, taking into account the level of susceptibility of the weeds and the economic damage thresholds for individual weed species (listed in the methodology). (Chapters 5.1.2, 5.1.3).	□/□	
6.	Monitoring the field from the time of emergence to the beginning of ripening, at least once a week, for the occurrence of diseases (Chapter 5.2.1).	□/□	
7.	Systematic monitoring of the field from the beginning of emergence until the beginning of ripening, at least once a week, for pest occurrence using appropriate methods (Chapter 5.3.1).	□/□	
8.	Use of plant protection products after exceeding the damage thresholds for diseases and pests (Chapter 5.2.3).	□/□	
9.	Application of at least one biological plant protection product treatment, if registered (seed treatment or plant spraying during the growing season), confirmed with a purchase invoice (Chapters 6.1, 6.2, 6.3)	□/□	
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 5.3.4).	□/□	

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)			
Item	Checkpoints	YES/NO	Comment
1.	Does the producer produce and protect the crops according to detailed methodologies approved by the Main Inspector?	□/□	
2.	Does the producer hold an up-to-date IP training certificate, subject to Articles 64(4), (5), (7) and (8) of the Plant Protection Products Act?	□/□	
3.	Does the producer only apply the plant protection products listed as IP-recommended products?	□/□	
4.	Are all required documents (e.g. methodologies, notebooks) available and kept on the holding?	□/□	
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 handle empty packaging of plant protection products and expired products 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 signalling of harmful organisms (wherever possible)?	□/□	
10.	Are plant protection product treatments carried out only by persons holding an up-to-date, as of the date of such treatments, certificate attesting to the completion of training in the scope of the application of plant protection products, counselling on plant protection products or integrated plant production, or any other document confirming the permission to apply plant protection products?	□/□	
11.	Are the applied plant protection products authorised for IP and for use 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 applied per unit area?	□/□	
13.	Were the plant protection treatments carried out under appropriate conditions (optimal temperature, wind below 4 m/s)?	□/□	
14.	Is the rotation of the active substances of the plant protection products used for the treatments respected whenever possible?	□/□	
15.	Does the producer limit the number of treatments and the amount of plant protection products used to the necessary minimum?	□/□	
16.	Does the producer have measuring devices to precisely determine	□/□	

Basic requirements (100 % compliance, i.e. 28 points)			
	the quantity of the measured plant protection product?		
17.	Are the conditions for safe use of the products respected, as set out on the labels?	□/□	
18.	Does the producer comply with the label instructions concerning the 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 respected?	□/□	
21.	Are the sprayers listed in the IP Notebook in good technical condition and are their technical inspection certificates up to date?	□/□	
22.	Does the producer carry out systematic calibration of the sprayer(s)?	□/□	
23.	Does the producer have a separate site for filling and cleaning the sprayers?	□/□	
24.	Does the handling of residues of the spray liquid comply with the indications on plant protection product labels?	□/□	
25.	Are plant protection products stored in an appropriately marked closed room in such a way as to prevent contamination of the environment?	□/□	
26.	Are all plant protection products stored only in their original packaging?	□/□	
27.	Does the IP producer 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 agricultural crops (minimum compliance 50%, i.e. 8 points)			
Item	**Checkpoints**	**YES/NO**	**Comment**
1.	Have the plant varieties grown been selected with respect to integrated plant production?	□/□	
2.	Is each field marked according to the entry in the IP Notebook?	□/□	
3.	Has the producer performed all the necessary agronomic procedures in accordance with the 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 spraying devices specified in the IP Notebook been used to perform the treatment?	☐/☐	
7.	Are fertiliser application machines maintained in good working order?	☐/☐	
8.	Do fertiliser application machines allow for accurate dose adjustment?	☐/☐	
9.	Is each fertiliser applied recorded in terms of 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 plant protection product 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 in the vicinity of the workplace?	☐/☐	
14.	Are hazardous areas on the holding, e.g. plant protection product storage rooms, clearly marked?	☐/☐	
15.	Does the producer use consultancy services?	☐/☐	
	Total points		

Recommendations (min. implementation 20%, i.e. 2 points)			
Item	**Checkpoints**	**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, for the persons who do not have the authority to use them?	☐/☐	
7.	Does the producer store on the holding only plant protection products allowed for use with the plant species they cultivate?	☐/☐	
8.	Does the producer improve their knowledge through integrated plant production meetings, courses or conferences?	☐/☐	
	Total points		

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