CHIEF INSPECTORATE FOR PLANT HEALTH AND SEED INSPECTION

DRAFT

METHODOLOGY
INTEGRATED PEPPER PRODUCTION
(under cover and in the field)

(4th edition)

Approved

by virtue of Article 57(2)(2) of the Plant Protection Products Act of 8 March 2013 (consolidated text: Journal of Laws of 2024, item 630)

by

the Main Inspector of Plant Health and Seed Inspection

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INTEGROWANA PRODUKCJA
URZĘDOWO KONTROLOWANA

Approved by
~~/signed electronically/~~

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I. INTRODUCTION

Integrated Production (IP) of plants is a modern food quality system, using in a sustainable way technical and biological progress in cultivation, fertilisation and plant protection, paying special attention to the protection of the environment and human health. The basic element of the system is the application of the principles of integrated plant protection, which apply to all professional users of plant protection products from 1 January 2014. These principles particularly prioritise the use of non-chemical methods which should be complemented by the use of pesticides when the anticipated economic losses caused by pests are higher than the cost of the treatments.

In the process of integrated production, it is very important to support natural biological mechanisms through the rational use of fertilisers, crop aids and plant protection products. Their use in modern agricultural production is necessary and extremely beneficial, but can sometimes cause a threat to the environment. Sustainable soil fertilisation and plant nutrition are designed to create a safe and efficient biosystem. This is equivalent to minimising chemical pollution from agriculture in soils and waters and, above all, in consumer yields while also having a positive impact on crop yield, consumer quality, and biological value. The rules for Integrated Production are set out in the Code of Good Agricultural Practice (DPR).

Among other things, application of IP is a guarantee of production of safe and high-quality food (not exceeding permissible residues of harmful substances), fewer inputs for production (application of fertilisers based on the actual demand of plants for nutrients, determined in particular on the basis of soil or plant analysis), and the rational use of plant protection products. Moreover, it helps reduce environmental pollution with chemical plant protection products, enhances biodiversity of agrocenoses and raises awareness among consumers and fruit and vegetable producers.

The certification system in integrated plant production is managed by certification entities authorised and supervised by provincial plant health and seed inspection services. Legislation on Integrated Plant Production is regulated by the *Plant Protection Products* Act of 8 March 2013 (Journal of Laws of 2024, item 63), the Regulation of the Minister of Agriculture and Rural Development of 24 June 2013 *on documenting activities related to integrated plant production* (Journal of Laws of 2023, item 2501), the Regulation of the Minister of Agriculture and Rural Development of 24 June 2013 *on the qualification of persons carrying out checks on compliance with the requirements of integrated plant production and the model certificate attesting to the use of integrated plant production* (Journal of Laws of 2024, item 180), and the Regulation of the Minister of Agriculture and Rural Development of 8 May 2013 *on training in plant protection products* (Journal of Laws of 2022, item 824).

The prerequisite for the IP certificate is managing production in compliance with this methodology which was approved by the Chief Inspector of Plant Health and Seed Inspection. The methodology of integrated pepper production covers all issues related to cultivation, fertilisation, and protection. From soil preparation, production and planting of seedlings, through agrotechnical treatments and protection against pests, to harvesting and preparation of peppers for sale. The methodology also takes into account the hygienic and sanitary principles to be followed during harvesting and preparation for sale of crops produced in the integrated plant production system and general rules for issuing certificates in integrated production. This methodology has been developed based on the results of our own research and the most recent published data, in accordance with the guidelines of Directive 2009/128/EC of the European Parliament, the International Organization for Biological and Integrated Control (IOBC) and the International Society for Horticultural Science.

II. AGROTECHNICS IN INTEGRATED PEPPER PRODUCTION (under covers and in the field)

Dr A. Stępowska, Dr N. Skubij, Eng. A. Długosz

2.1. Origin and description of the species

The genus pepper (*Capsicum* L.) belong to family Solanaceae. In the natural environment, peppers of this genus are perennial plants with a pungent taste. *Capsicum annuum* L. (annual pepper), the most important species of the genus *Capsicum*, is widely cultivated on a commercial scale. It is divided into three subspecies: subsp. *macrocarpum* (large-fruited pepper), sweet varieties; subsp. *microcarpum* (small-fruited pepper), mostly spicy varieties, and subsp. *fasciculatum* (bouquet pepper), ornamental varieties. Sweet pepper is a cultivated form of the species *Capsicum annuum* L. selected from wild populations (chili) in the 1820s in California. Since then, a large number of varieties have been created, differing in colour, shape, fruit size, and plant habit, as well as cultivation requirements and resistance to biotic and abiotic stress.

The fruit of the pepper is a berry, filled with air. On average, 80-95 % of water is contained in 100 g of the fruit purified from seeds, placenta, and stalk (one medium fruit), i.e. 5-20 g of such fruit contains all valuable nutrients and health-promoting substances, e.g. biochemically active carotenoid dyes: capsanthin, capsorubin, lycopene, lutein, and zeaxanthin. Very important in peppers are vitamins: provitamin A (alpha- and beta-carotene and cryptoxanthin 0.3-3.4 mg), B_1 and B_2, B_5 (pantothenic acid), B_6, B_7 (vitamin H, biotin), E (tocopherol), P (including rutin and lemon flavonoid), PP (niacin, nicotinic acid), which are among the strong antioxidants. However, the greatest importance is attached to vitamin C (ascorbic acid – 100-300 mg), the content of which depends on the type, variety and conditions of cultivation and is closely related to the amount of dry matter in the fruit. The less dry matter, which most often means greater juiciness of the flesh, the less vitamin C, unfortunately:

MORE vitamin C	LESS vitamin C
hot peppers	sweet peppers
red	green
green	‘white’
coloured	physiologically mature
thin-walled varieties	thick-walled varieties
field peppers	under cover
large spacing	high density
August	September
less irrigated	abundantly irrigated
on mineral wool	in soil
in soil	in organic substrates

In 100 g of fresh, ripe, sweet peppers, there are up to 3 g of sugars, of which 90-98 % are the simple sugars glucose and fructose, and the rest is sucrose. The amount of sugars depends on the variety, the stage of ripeness of the fruit and weather conditions. The sugar content increases as the fruit ripens, but decreases during storage. Pectins account for 3–7 % d.m., with 20 % of cellulosic fibrous substances, including dietary fibre. In 100 g of fresh peppers, there are 0.1-0.3 g (2 % dry matter) of amino acids. Fresh peppers contain approximately 0.4 % lipids, of which 82 % are neutral lipids, 2 % are phospholipids (containing the neurotransmitter choline, known as vitamin B_4), and 16 % are glycolipids. The fatty acids present in pepper seeds are mainly unsaturated acids, of which 40 % is linoleic acid (Omega 6), and approximately 50 % is oleic acid. Pepper seeds also contain oils that dissolve dyes, which is why powdered peppers (fruits ground with seeds) have a lighter but more intense colour than the raw material and do not clump.

The characteristic, burning taste of the fruit is caused by the alkaloid capsaicin (aromatic amine)**.** It is located in single, small, spherical secretory cells, similar to glands, near the conductive tissues of the fruit, most at the base of the placenta and septa, and least in seeds. In sweet peppers, capsaicin is considered absent (0 SHU (Scoville Heat Unit)). Capsaicin is determined by liquid chromatography (HPLC). The capsaicin content in green pepper fruits determined by the HPLC method was at the lowest level of 1 μg/g = approx. 16 SHU, while in hot chili peppers the smallest amount recorded was at least 2000 SHU. In hot peppers (>1500 SHU) and chili (>1500 – 2 million SHU), most capsaicin is formed when the fruits of hot peppers begin to discolour, especially at temperatures above 30°C, which is why the spiciest fruits come from extremely hot regions of the world. The taste and characteristic smell of fresh fruit are also influenced by organic acids and volatile oils containing, among others, alcohols, aldehydes and terpenes. In addition, peppers are a valuable source of potassium and phosphorus, with higher content than tomatoes, and they also have a lot of magnesium and calcium. In addition to basic micronutrients such as iron, manganese, zinc, and copper, it contains sodium and cobalt, which increase the activity of vitamin B_{12}.

2.2. Climatic and soil requirements, rotation

Pepper is a plant with high heat requirements. Temperature in the cultivation of this species is a factor inducing the formation of flower buds, flowering, and the setting and development of fruits. The optimum temperature range applicable to peppers throughout the growing season under cover and in the field is 18-32°C. During the seedling production phase, peppers require a maximum temperature of up to 26°C. After germination until pricking out, the temperature should be 18-20°C on a sunny day, 16-18°C on a cloudy day, and around 16°C at night. After pricking out from the first leaf stage, the temperature should be 22-25°C on a sunny day, 18-20°C on a cloudy day, and around 18°C at night. If the temperature drops below 14°C, plant growth is inhibited. The optimum temperature during the growing season conducive to fruit setting is 21-27°C during the day and 16-20°C at night. At a temperature of 27-35°C, peppers bloom and produce a very large number of flowers; however, flowers and buds drop. A temperature drop below 10°C before flowering results in the formation of multi-chambered, ‘tomato-like’ and often seedless fruits. Lowering the temperature at night below 15°C, during the setting of the fruit, results in the formation of small, thin-walled, and seedless fruits, and below 18°C – excessively elongated fruits with a rounded lower part. However, at a temperature of 0°C, the pepper plants die.

Pepper, as a thermophilic plant originating from the temperate climate zone, also has significant requirements regarding substrate/soil temperature. For the duration of cultivation, the substrate/soil temperature should not fall below 20°C or rise above 35°C. If possible, it should be kept more or less constant so that diurnal fluctuations are kept as low as possible. Ideally, the temperature of the substrate/soil during cultivation should be close to the outside air temperature. When the soil/substrate temperature drops below 14–15°C, the roots lose their ability to properly absorb water and nutrients, resulting in a physiological drought – plants shed flowers and buds. On the other hand, too warm growing substrate/too hot soil with a temperature above 25°C deteriorates calcium uptake and results in blossom end rot. Thus, ensuring an optimal substrate/soil temperature of up to 25°C promotes better growth and development of pepper plants.

Field cultivation of peppers is therefore better established in the warmer regions of the country, in sheltered sites, protected from cold winds, on well-warming soils and areas with a southern exposure. The field cultivation of peppers should be carried out in warm areas with a large number of sunny days during the growing season. The areas of southern Poland, i.e. in the Podkarpacie region from May to October and from the turn of May and June to September in the Sandomierz region, are beneficial for such cultivation. In central Poland and Kujawy, field crops can also be cultivated from the turn of May and June until the end of September. The fruits of peppers, in warm and sunny summers, ripen already at the end of July. In autumn, when all the fruits are already grown, the colouration is favoured by low morning temperatures (approx. 8–10 °C) and sunny warm days (approx. 20 °C) and a small amount of precipitation.

The light requirements of this vegetable are also high. Pepper is a plant with a strong photoperiodic reaction, in which the length of available light per day has a major impact on the early flowering and setting of fruits. Usually, the most intensive flowering of these plants is observed in early spring and autumn under cover cultivation, while in open field cultivation, it occurs in the second half of summer. Pepper is a vegetable that requires, in the juvenile phase – from the spread of the cotyledon to the appearance of the first flower buds – a daily exposure length of 10 to 12 hours. At a later date of seedling production, especially for field production, the length of daily exposure should be regulated by covering it. A short day is conducive to strengthening young plants, but with a day lasting about 8 hours, pepper plants will not set fruit. In the later stages of development, during the flowering and fruiting phase, the day should be longer; however, the optimal length of the day is 14-15 hours. In addition to the appropriate length of exposure during the day for proper growth and development during the growing season, peppers require intense light. Even in light shade, e.g. due to excessive density, young plants quickly etiolate, and the older ones bloom poorly and set and develop fruits inadequately. Optimal light conditions for the formation of flowers exist when the light intensity during this period (for about 50 days) is 3000 to 4000 lux for 14-15 hours a day. Faster development of the first fruits is favoured by a sixteen-hour light period with an intensity of 5,000 lux. In cultivation under cover from November to February, plants may experience light deficiencies. So, in order to obtain a strong and robust seedling during this period, it should be illuminated (with a light intensity of 5-10 thousand lux).

Peppers are a species with high water requirements. In the soil/substrate (at a depth of approximately 25 cm), constant humidity should be maintained to meet the water needs of peppers. Too high humidity causes root hypoxia and adverse pH changes, while water deficiency negatively affects the growth and functioning of the plant. Therefore, fluctuations in the moisture content of the substrate/soil, regardless of the stage of development, should not be greater than 10-15 %. The optimal water content for 2-3 weeks after planting is 60-70 % of the field water capacity (FWC), then it gradually increases and during the period of intensive fruit formation reaches 80 %.

In the cultivation of peppers, the relative humidity of the air is an important issue. This parameter is of particular importance during the flowering and fruiting period of pepper plants, where it should be 70-80 %. With air humidity above 95 %, intensive vegetative growth of plants is observed; the fruits have a greater mass, however, there are fewer of them, as some of the flower buds fall. On the other hand, too low air humidity, below 60 %, increases transpiration, causing plants to quickly wither, shed flower buds, and exhibit blossom end rot on the fruits.

Pepper is a species requiring soils that are fertile, humus-rich, airy, in good condition, classified as class II and III, with very good and regulated air and water conditions. In weaker sites, cultivation is possible, but only if a fertigation system is used, supplying all the minerals necessary for the proper growth and development of plants. If the cultivation of peppers is to be planted under cover, it can be carried out, among others, in organic substrates, e.g. in peat or straw, as well as in inert substrates, i.e. mineral wool. When choosing substrates for growing under cover, it is important to know their physical properties (i.e. bulk density, porosity, water capacity, retention capacity, humidity, plasticity), facilitating the establishment of a crop fertilisation program.

Pepper is a plant that does not react specifically to the preceding crop, however **in rotation, it should not be grown after itself or other plants of families Solanaceae and Cucurbitaceae in the same field more frequently than every 4 years.** Shorter breaks in cultivation are not advisable due to the possibility of the same soil pathogens and the likelihood of risk from fungi of the genus *Fusarium* and *Verticilium*, causing vascular diseases of plants. Pepper plantation sites should also not be located in fields previously used for meadows and tall grasses, as they leave favourable conditions for the occurrence of wireworms, which damage the roots of plants. A good precursor crop includes brassicas, onions, as well as legumes or cereals. In crop rotation, it is also important to take into account the use of catch crops, cover crops, and undersowings from mixed species, particularly those with phytosanitary properties (i.e., mustard, phacelia), which positively affect the soil and create good conditions for the development of many beneficial soil microorganisms, thus reducing the risk of diseases manifested by wilting of plants.

Highly specialised farms producing peppers in the ground under cover do not have the possibility to apply crop rotation or full-scale crop rotation, due to market conditions of production, which do not allow for diversification – a business strategy of the assortment while maintaining the economic efficiency of production. There is, however, the possibility of periodically or annually excluding the most pathogen-infected objects from cultivation and performing treatments to improve the phytosanitary condition of the soil, through disinfection, liming, or the introduction of catch crops, cover crops, or seedlings from mixed species with phytosanitary properties. In farms equipped, for example, with 20 standard tunnels, with a total area of approx. 0.5 hectares, it is recommended to use precursor crops, but no longer than until mid-April. However, in tunnels with movable structures, i.e. foil tunnels and in wooden tunnels before the first year of growing peppers, it is best to introduce legumes, brassica and onion vegetables, and all plants for green fertilisers, with the exception of perennial grasses, as precursors. Direct precursor crops in subsequent years can be radishes, lettuce, early carrots, or beets for greens, and other vegetables harvested no later than mid-April.

2.3. Cultivation of peppers

2.3.1. Place and time of cultivation

Pepper is a vegetable, the cultivation of which can be successfully carried out in an enclosed space – facilities under cover, as well as in the open – in the field. The location of the production of this species depends on the capabilities and preferences of the farm in relation to the facility or land owned and the distribution of weather conditions in the region.

In facilities under cover, heated greenhouses are used to establish pepper cultivation as early as possible, starting from January. However, from March, peppers are planted in heated tunnels, which can have a steel structure with a side pipe system and vegetative heating (heating pipes on the ground surface) or blown-air heating. For plantings at later dates (May-June), covers without heating are useful, i.e.:

- movable foil tunnels (approx. 140-170 cm);
- high, wooden (min. 2.5 m at the ridge);
- freestanding, standard (6-8 m x 30 m), of approx. ridge height 3.5 m, made of steel bars, with traditional peak ventilation (door);
- free-standing large-area (>8 m x at least 60 m), ridge height 3.5-4.5 m, made of galvanised tubes or steel sections, with gable and side ventilation or a roll-up roof;
- blocked (nave area of at least 250 m^2), ridge height (3.5–5 m), of galvanised tubes, steel or aluminium sections, with top, upper, side or roll-up ventilation in the case of gable roofs.

Tunnel facilities for the cultivation of peppers are covered, among others, with polyethylene foil, stabilized against UV rays, heat (IR) and water vapour condensation (antifog), with a thickness of 0.16 mm to 0.2 mm, colourless or yellow, having the best light transmission. The improvement of thermal conditions in tunnels is also ensured by a double inflatable foil, the so-called airbag, on the side walls and/or roof surface. Large tunnels may have walls made of double-chamber polycarbonate.

In greenhouses and interlocked high tunnels, it is possible to install heat-insulating curtains and shade cloths with manual or automatic drive. Shading the remaining tunnels, on the other hand, involves spraying the outer coatings with a chalk solution or special preparations. As a mechanical protection against pest infestation, protective meshes with a mesh diameter of 1-1.5 mm can be installed on doors and vents.

In facilities under cover, irrigation and dosing systems can be installed, supplied from the mains or a standing water tank, used for watering the crop, but also for top dressing (fertigation). The basic equipment includes a fertiliser dispenser (or a set of dispensers) with a capacity of at least approximately 2.5 dm^3/emitter/hour, preferably with a pressure equalization valve (compensating emitters) and at least one disc filter for water (minimum 120 Mesh). In addition, solenoid valves can be integrated into the system, allowing for control of the working time of the set and dosing the medium in divided doses, as well as controllers programmed for irrigation of multiple sections at different times. In modern facilities, climate computers with sensors that monitor various air and substrate parameters and control ventilation, irrigation, shading systems, etc., are effective.

Thus, due to the place of cultivation, peppers can be grown in the greenhouse the earliest and for the longest duration in the season (from the end of January to December). However, cultivation in this facility is associated with high heating costs, lighting of the crop, and thus the potential low profitability of production. More often, pepper cultivation is carried out in heated tunnels, where it is planted from the end of February (depending on the persisting temperatures). The production established in heated tunnels requires less outlays and allows for the extension of cultivation in the autumn (e.g. until the end of November). In foil tunnels, peppers are most often grown in the Podkarpacie region, where, thanks to favourable light conditions in the south of Poland, the small volume of the tunnel heats up quickly, allowing for an early planting date (second to third decade of March). However, in central Poland (Radomsk region), the most common period for planting peppers is from the second decade of April to the beginning of May, when spring frosts can be avoided in unheated tunnels. When deciding to grow peppers in open ground, field plantings last from mid-May to the end of June. However, it should be taken into account that the climate in Poland is unpredictable, and crops directly exposed to a few hours of temperature drop to approximately 0°C will be destroyed regardless of the season. The dates for planting peppers depending on the type of growing location and temperature are shown in Table 1.

Table 1. Agrotechnical timing in the cultivation of peppers

place of cultivation	Sowing of seeds	Planting of seedlings	Beginning of harvest		End of harvest
			'green'*	coloured	
greenhouse	early December**	late January – early February	March	April	November – December
heated tunnel	early January **	late February – early March	May	June	November
unheated high tunnel	early March	turn of April and May	late June	mid July	late October
foil tunnel	early February**	late March	late May	late June	October
field	early April	after 15 May - late June	early August	mid August	late September

*'green' refers to the first stage of consumer ripeness (table ripeness), irrespective of the colour of the fruit (shades of green, cream, purple, navy blue, brown) before the final colour is red, yellow, or orange
** - necessary illumination of seedlings

2.3.2. Methods of cultivation

Depending on the place of cultivation, peppers are produced by different methods. In heated rooms – greenhouses and tunnels – pepper cultivation can be carried out in the ground, in rings, on straw bales (so-called heating substrates), in cultivation bags (growing mats), and inert substrates (i.e., mineral wool, coconut fibre). In unheated tunnels, the most common cultivation method is soil cultivation, which is also used in open spaces for field plantings of this species. In unheated tunnels and greenhouses, it is also possible to cultivate in rings or on straw bales.

2.3.2.1. Field cultivation in facilities under cover

Preferred are greenhouses, tunnels with soil/substrate with high permeability, allowing the leaching of excess salt accumulated over time during cultivation. Also, rapidly warming soils/substrates.

Due to the requirements of peppers regarding soil/substrate temperature, when growing directly in the ground in early spring, they should be planted in facilities equipped with heating pipes, not only above the surface but also in the soil. Pepper plants are then planted depending on the arrangement of the pipes, e.g., in 2 rows running over the pipe 60 cm apart, leaving strips 35 cm wide on the side. With such spacing, there are 4 plants per 1

m^2,and the plants should be trained to grow on 2 shoots. If the spacing between the rows is 60 cm, in the row 45 cm, and between the strips 90 cm, the pepper plants can be trained to 3 shoots. It is important to turn on the heating 3-4 days before planting to warm the soil. It is also necessary to level the soil surface and designate planting sites. The seedling is planted 1-1.5 cm deeper than it grew in the pot. After planting, it is necessary to water the peppers with approximately 0.5 litres per plant.

In heated tunnels, the side heating system should be turned on at least 5-7 days before planting. However, in unheated tunnels, where the foil is removed for the winter, it should be applied as early as possible or at least 2-3 weeks before the planned planting of peppers. Under the foil, the soil heats up faster and air-water conditions are regulated more effectively. With dry soil after winter, the tunnel should be closed, and when the humidity of the substrate is very high, the tunnel should be left open to increase evaporation. In both cases, the effect of heating the soil and improving water relations is achieved. Immediately before planting, the soil must be levelled and the arable layer irrigated so that at the time of planting its moisture content is at the level of 60-80 % of field capacity. The spacing of pepper planting in the above facilities should be adapted to the growing area and the selected variety.

2.3.2.2. Cultivation in rings in facilities under cover

It is a cultivation method that ensures lower substrate consumption, maintains a temperature similar to the ambient temperature in the ring, ensures better air relations of the root mass, and more efficient uptake of water and nutrients by the roots compared to flat pepper cultivation. Recommended for facilities without soil heating, as it allows for early pepper cultivation.

For growing peppers, rings with a capacity of 5 litres, having a height and diameter of about 20 cm, are recommended. Rings, also known as cylinders, are pots made of PP or PVC foil and are placed on tables or on the soil surface in a ground facility under cover (i.e., greenhouse, tunnel). When the crop is placed on the tables, the substrate layer on them should be 10 cm. For example, if the table is 1.8 m wide, peppers should be planted in 4 rows. However, when the rings are placed on the ground, they can be placed directly on the decontaminated and levelled soil surface in the strip-row system (2 rows located 60 cm apart, followed by a 90 cm strip, and then another 2 rows separated by 60 cm, with plant spacing maintained at 35 cm within the row). In a situation where the soil has not been decontaminated, a recess 10 cm deep and 100 cm wide should be dug first, in which the foil is placed, after which the recess is filled with decontaminated or fresh substrate. It is only on this substrate that rings are placed in a belt-row system (2 rows located 50 cm apart, then a belt of 100 cm is introduced and another 2 rows separated by 50 cm, with plant spacing maintained at 35 cm within a row). The rings are filled with a ready substrate, i.e. peat substrate or peat-bark substrate, saturated with nutrients sufficient for the first 3-4 weeks of cultivation. The substrate for the rings can also be self-made, about 2-3 weeks before planting pepper plants. The following proportions shall be retained in the mixture: 1/3 of composted pine bark and 2/3 of high moor peat, along with the addition of fertilisers containing basic macro- and micronutrients. The substrate can also be mixed with compost (1 part compost to 4 parts peat-bark substrate), which reduces the consumption of fertilisers, especially micronutrients necessary to saturate the substrate. In substrates prepared independently, after a few days, it is necessary to perform a neutralisation curve for calcium and, according to it, adjust the pH of the substrate to 6-6.8 by adding an appropriate amount of calcium, e.g., in the form of chalk or dolomite. Analysis of the prepared substrate for rings is performed about a week after deacidification. In the case of slight incompatibility of the results with the required level, the correction should be made after plant rooting – by sprinkling each ring or in the form of a nutrient solution.

2.3.2.3. Growing on straw bales in facilities under cover

The method of growing peppers on straw bales, known as biologically heated substrates, is used when planting seedlings in winter (February-March) in greenhouses and tunnels heated by a side heating pipe system, to provide plants with more favourable temperature parameters in the root zone. Simultaneously, due to the temperature that straw reaches after heating, it can also be used for early planting of peppers in unheated high tunnels. In addition, the straw isolates plant roots from the parent soil and reduces the risk of soil-borne diseases, especially if the straw is laid on the foil. The foil protecting the bottom and sides of the bales also limits the release of unused fertilisers into the soil.

The heating substrate consists of hard straw bales (rye, wheat, or rapeseed), most often with dimensions of 40x50x60 cm or 40x60x80 cm. Depending on the width of the structure and the size of the bales, as well as the expected growing season, the planting schedule, and the method of plant cultivation, varying quantities of bales are used. It is assumed that there are about 5 kg of straw per plant. The traditional method of cultivation on bales of straw consists in saturating it with fertilisers and water in order to heat (fermentation process) and build a sorption complex. To facilitate the rooting of the seedbed, the top of the bales is covered with a cover of peat bedding. The straw preparation process takes 1–3 weeks depending on the ambient temperature. Non-heated straw prior to planting and free of peat cover is treated slightly differently. Immediately after laying and slightly moistening the bales, seedbed rings are placed on their surface (preferably with a larger diameter than the traditional 10-12 cm). In order to make the roots outgrow the substrate better, bores with a depth of approx. 5 cm can be cut into the bale, in which seedlings are inserted.

2.3.2.4. Cultivation in bags in facilities under cover

Growing bags (cultivation mats), i.e. substrate with parameters corresponding to a given crop, packed in bags made of polyethylene, white and black foil, are gaining increasing popularity. Due to the small height of the sacks, this is the only way of planting peppers in isolation from the soil, possible to use in foil tunnels.

The sacks are placed on a Styrofoam foundation covered with foil. Styrofoam allows thermal insulation from soil, while foil prevents fertilisers from entering the ground and further into groundwater. In the top foil, seedling holes are cut and irrigation pipes are introduced. Drip lines are used, which are threaded under the cover of the bag, through incisions in the foil on its shorter side. One line is enough for one sack, even if two rows of plants grow on it. The daily dose of the solution should not exceed 1 L per plant. To avoid flooding the root system, on the long sides of the sacks, close to the surface of the ground, two 3 cm incisions need to be made to allow the excess of liquid to flow out.

Pre-packed peat beddings contain all the ingredients needed for the first 3–4 weeks of growing. The same applies to peat substrate prepared independently (on the same principle as in cultivation in rings). You can also use chopped straw and its mixtures, for example with bark or sawdust, to fill the sacks. Rye straw cut into 0.5-1 cm sections is packed under pressure in bags measuring 100x20x10 cm. The preparation of a greenhouse or tunnel when using straw bags is the same as for bags with peat substrate. However, straw beddings are not saturated with nutrients before packaging. Soaking with the nutrient medium is carried out the day before planting plants.

2.3.2.5. Cultivation on mineral wool in facilities under cover

In heated greenhouses, where there are opportunities for almost year-round cultivation of peppers, mineral wool and coconut fibre mats work very well as a growing medium. However, in order to obtain a high commercial yield of peppers in inert substrates, specialised equipment is required to control and manage the climate and fertilisation. In addition to the standard side heating, crops on mineral wool should have surface heating, as well as a ventilation system, and the plates should be laid on polystyrene covered with white foil. The foil is mulched over the entire surface of the greenhouse. It provides better lighting for cultivation in the winter/spring months, protects against drainage of drainage water to the soil and facilitates the maintenance of good phytosanitary condition of crops. For growing peppers, mats 100 cm long, 15 cm wide, and 7.5 cm thick are usually used, which are surrounded by foil that reduces evaporation and protects against the development of algae. Mats are laid in double-row belts. It is advisable that the distance between the centres of the rows be 50 cm, and between the strips 100 cm. On a mat with a length of 100 cm, 3 plants are planted every 33 cm. In each mat, holes are made with an area slightly larger than the base of the cube with a young seedling. This method, due to the complete isolation of the root system of plants from the substrate, makes it possible to grow in rooms where the substrate is unsuitable or infected, and for technical or economic reasons it cannot be treated. In addition, compared to cultivation in organic substrate, fruits grown in mineral wool have better performance (the seed cavity and stalk constitute only approx. 10 % of the fruit's weight), and contain more dry matter, sugars, and vitamin C.

2.3.2.6. Growing peppers in the field

Pepper seedlings are planted in the field at the turn of May and June, flat, most often with a spacing of 40-50 x 30-40 cm. They can also be planted in strips in 4 rows 30-40 cm apart, leaving the fifth row free, or in spacings adapted to the equipment available (planter, weeder), not deeper than the height formed by the container. When planting pepper seedlings, great attention should be paid to their density, which is approximately 33,000-35,000 plants per hectare. It is of great importance due to the heavy load of fruit on plants.

When they are planted too sparsely, they are unable to maintain a vertical position and may topple over, which increases fruit loss. Fruits from overturned plants will not mature and will wither quickly. On the other hand, plants planted in high density will lean on each other and will not fall so easily. However, such density, especially in wet years, can cause a greater severity of diseases. Therefore, they should be well protected to prevent infection.

2.3.3. Production of seedlings

In Poland, peppers in the field production system and under cover are grown exclusively from seedlings, and the length of the seedling preparation period depends on the date of planting the plants in a permanent site. It is assumed that it is about 7-8 weeks.

The best conditions for the production of pepper seedlings are provided by modern specialised greenhouses; however, economic greenhouses, the so-called multipliers, or heated tunnels can also be used for their preparation. Such facilities must be suitably adapted to prevent heat loss and equipped with side heating or heated openwork tables for the production of seedlings in multipots, lighting systems (including high-pressure sodium lamps with a power of 400-600 W or LED lamps with an emission power of 130-180 $\mu mol/m^2/s$), and an irrigation system (i.e., suspended micro-sprinklers, high-pressure sprinklers).

If there is no technical infrastructure to prepare seedlings, they can be purchased. There are many seedling producer groups on the market, offering both pricked-out seedlings and seedlings ready for planting under cover or in the field. **In integrated pepper production, in the case of purchasing seedlings, it is necessary to store the proof of purchase, the supplier's document, and the plant passport.**

<u>Seedlings for cultivation under cover</u> are usually produced in two stages. Due to space constraints and the high thermal and light requirements of peppers at this stage, seeds are first sown into sowing boxes and then transplanted into larger containers at the cotyledon stage with a visible bud of the true leaf. **In the integrated cultivation of peppers, it is recommended that the production of seedlings be carried out with vegetable seed of at least standard category. It should be also remembered that labels, plant passports and proof of seed purchase must be retained.** Pepper seeds germinate slowly, so in order to speed up this process, they can be soaked for two days before sowing in water at a temperature of 25-30°°C, and then after drying, seasoned. For sowing boxes, the seeds are sown in rows, 4-5 cm apart, and between the seeds in a row every 1 cm. Seeds are sown to a depth of 0.5 cm. They should be covered with sand mixed with sieved peat substrate or with sand alone. In the boxes, seeds can also be sown broadcast, but care should be taken to ensure that they are evenly distributed over the entire surface. With the right thermal conditions, seedling emergence is observed after 9-11 days. In the production of seedlings from sowing until mid-March, it is necessary to illuminate seedlings after the appearance of cotyledons.

After two weeks from emergence, when the seedlings have developed cotyledons and the beginning of the first true leaf, they are pricked out. Seedlings can be pricked out into PE rings with a diameter of 10-12 cm (capacity 0.7 dm^3), PE pots with a diameter of 10 cm (capacity approx. 0.5 dm^3), and soil or peat cubes with dimensions of 7.5-10 cm x 7.5-10 cm (capacity 0.4-1 dm^3), which provide favourable conditions for root development. Then the containers are placed on solid, levelled tables lined with foil. It is also possible to transplant plants into multipots with a cell capacity of 0.09 dm^3 (54 cells in a tray), but such containers must be placed on openwork tables (e.g. a bottom made of hard, deformation-resistant mesh).

Seedlings for field cultivation are produced in one step, by sowing directly into multipots with a peat substrate (preferably 54 cells per tray), from the beginning of April. At this time, seedlings do not require lighting and feeding, although growth stimulators can be used to improve the structure of the root system. After obtaining 10-15 centimetre plants, the seedlings must be hardened by exposing them outside the propagators, preferably in a covered seedbed. Peppers do not tolerate excessive drying, but the seedlings should be protected from heavy rain and hail. Properly produced seedlings should be stocky with a strong root system, dark green and non-woody, have 8-10 leaves and be in the stage of creating flower buds.

In the integrated production of peppers, seedlings should be prepared in peat substrates, free from pathogens and pests, and should be confirmed with proof of purchase of the substrate. High moor peat is best used for the production of seedlings. It is also possible to produce cubes (pressed under pressure) from a decontaminated mixture of compost earth with clay, sand, or manure. The composition must be selected so that its total porosity is about 80 %, and the field's water capacity is about 70 %.

In the production of seedlings for growing on inert substrates (i.e. mineral wool), pepper seeds are sown in mineral wool sticks, which are soaked in a nutrient solution with an EC of 1.8-2.0 and a pH of approximately 5.5. After sowing, the seeds are covered with a thin layer of vermiculite and protected against drying, e.g. by covering with foil. When the seedlings begin to appear on the surface, the foil should be removed. During germination, the temperature should be maintained at 24-26˚°C, and after emergence, it should be reduced to 22°C during the day and 20˚°C at night. Seedlings with two true leaves are transplanted into mineral wool cubes (dimensions 10x10x6.5 cm, with a hole diameter of 2-2.5 cm and a depth of 1.5-2.5 cm). 2-3 days before transplanting, the cube seedlings should be placed on tables lined with white foil and soaked with a medium with EC 2.0-2.2 and pH approx. 5.5 (white foil on the tables improves light conditions). During the growth of seedlings, the temperature in the cube should be 20°C, and the ambient temperature during the day 20-22°C, or 18-20°C at night. If necessary, the medium in the cubes should be replenished, providing it in such a quantity that the cubes are sufficiently moist, but so that the medium does not flow onto the backing foil. Ready for planting, the seedling should be stocky, have 8-10 leaves, developed flower buds, and the cube completely overgrown with roots.

2.4. Fertilisation

2.4.1. Fertilisation of peppers in facilities under cover

The nutritional requirements and fertiliser needs of peppers grown under cover are quite high due to the intensive growth of vegetative and generative organs throughout the growing period. Fertilisation applied in facilities under cover, due to different types of cultivation methods and the use of substrate or soil, is variable.

1) ***Coil cultivation of peppers in a confined space***

In the field cultivation of peppers in a foil tunnel the fertilisation programme applied should take account of pre-vegetation fertilisation, top dressing through fertigation and possible supplementary foliar feeding. **In integrated field cultivation of peppers under cover, before the planned start of cultivation, it is necessary to perform a soil nutrient richness analysis. Based on the results of the analysis, it is necessary to determine the fertiliser needs and apply optimal fertilisation for the cultivated plant.** Soil analysis should be performed at District Chemical and Agricultural Stations or other accredited laboratories (accredited in accordance with the Journal of Laws of 2002 No. 166, item 1360, or the provisions of Regulation (EC) No 765/2008 of the European Parliament and of the Council). The nutritional requirements for peppers during the various stages of development in the growing season are shown in Table 2.

Replenishment of soil should always be based on the results of its chemical analysis. In the case of facilities with foil left for the winter, soil samples can be taken after the end of cultivation. From the soil left uncovered until spring, it is best to take samples in early spring, after the ground has thawed (II/III).

Table 2. Dietary requirements for large-fruited pepper varieties in open field cultivation under cover in subsequent growth phases (mg/dm^3 soil/substrate)

Growth phase	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Magnesium (Mg)	Calcium (Ca)	Other ingredients
Seedlings (for sowing)	80-100	100-150	125-150	100-125	800-1000	S-30-60 Fe-3.0 Mn-0.4 Mo-0.01 Cu-0.2 Zn-0.2 B-0,3
Seedlings (for pricking out)	125-150	125-175	175-200	125-150	1000-1250	
Intensive vegetative growth	200-250	200	300-400	120-150	1800-2500	
Full flowering	180-200	150-350	300-400	120-150	1800-2500	
Full fruiting	180-200	150-250	300-400	100-120	1800-2500	

At the stage of pre-vegetation fertilisation, special attention should be paid to the appropriate amount of calcium, as this element is difficult to supplement during cultivation. The soil pH in the cultivation of peppers under cover should be close to neutral, pH 6-6.8, and salinity at the level of 1.2-1.5 g NaCl/dm^3. If the soil pH, determined on the basis of soil samples, is below the specified range, liming should be applied. The dose of lime needed to deacidify the soil is best determined on the basis of a marked neutralisation curve. Depending on the soil's pH, its calcium content, and the timing of liming, different calcium fertilisers are used. In autumn, quicklime is most often recommended (it releases calcium quickly and significantly reduces soil acidity), very early in spring – dolomite, up to two weeks before planting – chalk (calcium carbonate, decomposes gradually and causes a long-term change in soil pH), immediately before planting and during cultivation – calcium nitrate (provides calcium within approximately 5-7 days, but does not change the soil pH).

In facilities where the foil is removed for the winter and fertilisation with manure, compost or green fertiliser is applied, the planned fertilisation should take into account the amount of components that will be released as a result of the mineralisation of the organic matter brought into the soil from these fertilisers. For this purpose, the so-called fertiliser equivalents for the applied organic fertiliser given in the Code of Good Agricultural Practice should be used. If natural and organic fertilisation is not applied in tunnels, mineral pre-vegetation fertilisation should be performed after the application of the foil, as in other facilities, based on the results of the chemical analysis of the soil.

Pre-vegetation phosphorus fertilisation is applied 7-10 days before planting the seedlings, because the phosphorus released after this period will be available to the roots immediately after planting the plants. If organic fertilisation is used in the cultivation of peppers, the amount of potassium fertiliser is approximately 3.30 kg K_2O per 100 m^2, applied in divided doses. In tunnels with removable foil for the winter, 1/3 of the dose is applied in the autumn (in the form of potassium salt), 1/3 before planting, and 1/3 as a top dressing (the remaining doses in the form of potassium sulphate). On poor soil, 20 % of fertiliser is used in autumn, 30 % before planting and 50 % during cultivation. However, in facilities covered with foil for the winter, the potassium fertiliser used in spring is potassium sulphate or potassium nitrate. The dose in this type of facility can be applied in full or divided into two parts, with one part applied pre-vegetatively and the other as a top dressing. The use of an increased pre-vegetation dose of nitrogen at this stage makes it possible to fertilise N more sparingly during fertigation (over-fertilisation with this component in later stages of development delays the ripening of the fruit). Before planting, a dose of approx. 1.5-2 kg N per 100 m^{2}shall be applied, with the remaining amount of nitrogen applied as a top dressing.

Fertiliser mixtures and compound fertilisers can also be used for pre-vegetation fertilisation of peppers. The advantage of these fertilisers is a good balance of the composition and a more effective impact on the sorption complex than single fertilisers. To a lesser extent they are eluted and reduce the salinity of the substrate. Some of these types of fertilisers contain certain organic ingredients, and their action is spread over several weeks. The recommended dose is 2–10 kg/100 m^2 depending on the composition and abundance of the soil.

Due to the fact that peppers produce a fibrous root system, the most intensive nutrient uptake takes place from a depth of about 30-50 cm and an area of about 0.5 m^2 of soil. Top-dressing fertilisation of pepper crops does not start immediately after planting (this is a deliberate action aimed at stimulating the roots to grow in search of moisture in the deeper layers of the soil, allowing for better establishment of the plants). To prevent excessive loss of turgor, plants can be sprayed during this period. In general, watering begins 3-5 days after planting, while fertigation is recommended to be incorporated into the crop 2-3 weeks after planting the pepper seedling in the tunnel. Top-dressing fertilisation of peppers, grown on soil properly fertilised before the growing season, begins only when the fruit sets on the first tier of the crown, whereas with inadequate soil fertility, a nutrient solution of a specific composition is introduced immediately after the plants have rooted. The frequency of fertigation in the field cultivation of tunnel peppers depends on weather conditions. For example, after abundant watering, cloudy days may occur, during which the evaporation of water in the facilities will be minimal, making it possible to reduce the frequency of fertigation. Approximately 0.5-0.7 L of nutrient solution should be provided per plant. It is preferable to include fertigation with smaller doses, but at shorter intervals. The composition of the nutrient medium supplied to plants should be regulated in relation to the nutritional requirements of plants in individual developmental phases (table 2). It can also be modified depending on the condition of the plants (e.g. excessive development of green mass - more potassium, less nitrogen), as well as weather conditions (e.g. more concentrated medium during cloudy weather, more phosphorus during spring cold).

In the field cultivation of peppers, depending on the cultivated area, fertiliser dispensing devices with a simple injector structure or more complex ones in the form of fertiliser mixers can be used for fertigation. One of the most commonly practised solutions is proportional dispensers, allowing for the regulation of the appropriate concentration of fertilisers. When using fertiliser mixers for fertigation, the concentration of the medium is adjusted through its EC. In the cultivation of peppers during the initial growth period, an EC of 1.2-1.4 is recommended. When the first flowers appear, the EC should be 1.6-2.0, and during the phase of abundant fruiting, it should be 2.2-2.4. When there is less fruit, the EC should be 2.0. The pH of the nutrient medium in the cultivation of peppers should be at the level of 6.0-6.2. The addition of nitric or phosphoric acid should be taken into account when establishing the medium on the basis of the EC. For the preparation of media, only fully soluble fertilisers are used: ammonium nitrate, potassium nitrate, calcium nitrate, or calcium-magnesium nitrate. The administration of nitrogen fertilisers in ammonium form (ammonium nitrate, ammonium phosphate) should be limited to a period of intense vegetative growth, i.e. approx. 4-6 weeks after transplanting the seedlings. Later on, the $N\text{-}NH_4$ form adversely affects the wall thickness and colouration of the fruit. Fertilisers used for the composition of media include potassium monophosphate; less frequently, ammonium phosphate is used as a source of phosphorus (primarily during the phase of intense vegetative growth); possibly soluble potassium sulphate and magnesium sulphate. If necessary, nitric or phosphoric acid is used to acidify the medium, which are also sources of both macronutrients. Peppers have high requirements for calcium, so it is necessary to successively apply it to the roots, preferably in the form of calcium nitrate (1 kg of fertiliser/1000 L of working solution). In crops in the ground, especially after manure, micronutrients can be given several times during cultivation, preferably in the form of multi-component micronutrient fertilisers. In the case of fertilisers with a constant composition, the availability of ingredients should be regulated by changing the concentration of the medium from 0.2 % to 1 %. In each irrigation cycle, there should be a 0.05-1.5 % solution of fertilisers.

In the course of cultivation and applied top dressing, it is important to perform a chemical analysis of the soil from under drip-irrigated plants. The sample should be taken from a place 10-15 cm away from the emitter, i.e. most often from the centre of the inter-row space and at a depth of 20 cm. The nutrients are moved along with water to this depth, into the zone of the most active roots. Thus, the obtained results of the analysis will be close to the existing state of soil fertility. With constant fertigation, the depth of sampling is 10–15 cm, because continuous feeding promotes the shallow growth of roots. It should be noted that with proper growth and development of the plant in a good substrate, the sample taken about 24 hours after the last fertilisation may almost completely lack nitrogen. Other nutrients are captured much slower, so the correct results of such analysis should show only about 50 % of the optimal level of K and 80 % at this point. It should also not be alarming to see approx. a 30 % increase in Mg and Ca content. In excessively moist soil, the roots are often hypoxic and do not absorb magnesium, whereas in dry soil, the roots do not absorb calcium. If the results of the analysis show too high a concentration of salt in the substrate/soil, it is necessary to increase the water dose for a while and/or reduce the concentration of the medium (by 30 % at a time) or change its composition by giving up, for example, potassium sulphate in favour of potassium monophosphate.

Increasing the nutrient richness of the substrate/soil should be based on the results of chemical analyses of the substrate/soil, both before and during cultivation.

Foliar feeding of peppers is introduced primarily in situations of abiotic or biotic stress caused by variable thermal-humidity conditions, especially during the acclimatization phase of plants after planting, as well as during the period of flowering and fruiting. More often, this is needed in non-specialised facilities (i.e. unheated tunnels), during the cold period, after the peppers have been planted, and during the flowering of the first tier of the crown. At the same time, plants should be preventively sprayed with a calcium nitrate solution (0.5% for nitrate with a content of approx. 19 % Ca and 13-15 % N; 0.1 % – for most liquid saltpetre). Foliar feeding with nitrogen is relevant only in the case of general weakening of growth (despite favourable temperatures), as well as after the mass occurrence of aphids or spider mites, or severe damage to plants (leaves covered with sooty mould, drying, falling). Foliar spraying with a 0.5 % urea solution or a multi-component fertiliser, the so-called balanced fertiliser (i.e. NPK 19-19-19, NPK 12-12-12) can be used to stimulate the development of new leaves. During periods of significant daily temperature fluctuations, if it is not possible to supplement this component through root application, foliar potassium fertilisers are used. In field cultivation, micronutrients are absorbed quickly, and peppers rarely suffer from their deficiency (usually most after root flooding). In such case, 1-2 sprays with multi-component micronutrient fertilisers are sufficient, preferably with magnesium, which stimulates the synthesis of chlorophyll. It is also worth using them after each large harvest, because during intense fruiting the ability to exchange ions decreases, the value of the substrate/soil pH increases, so that the roots take up fewer of these components. It is also important to foliar feed peppers with calcium, which is intended to supplement the deficiencies of this element in the plant and prevent blossom end rot of the fruit. Calcium nitrate or calcium chloride can then be used. However, in order for the treatment to be effective, the buds must be carefully covered with the calcium preparation.

Examples of fertigation of pepper in the field cultivation under a cover, known as the

- „POST MANURE"
  - Manure–300 kg/100 m^2 (in the autumn).
  - Pre-vegetation fertilisation depending on the results of soil analysis.

Periodic fertigation (per 1000 L of nutrient solution)

6 weeks after planting – fertilisation every 3–4 days (1–1.5 L/plant)

- multi-component fertiliser (10 %–14 % N, 20 %–30 % K) – 1–1.2 kg;
- monopotassium phosphate – 0.3 kg;
- crystalline calcium nitrate (15 % N + 19 % Ca) – 0.7 kg or liquid (7.5 % N + 9.5 % Ca) – 1.5 L;

week 9 until the end of September – fertilisation every 2–3 days (1.5–2 L/plant)

- multi-component fertiliser (10 %–14 % N, 20 %–30 % K) – 1–1.3 kg;
- monopotassium phosphate – 0.2 kg;
- magnesium sulfate heptahydrate – 0.4 kg;
- crystalline calcium nitrate (15 % N + 19 % Ca) – 1 kg or liquid (7.5 % N + 9.5 % Ca) – 2 L;
- if there is no micronutrient in the macro-element fertiliser – 100 ml of micronutrient fertiliser – once a week

Daily fertigation (per 1 000 L of nutrient solution):

6 weeks after planting (0.7–1 l/plant)

- multi-component fertiliser (12 %–14 % N, 20 %–30 % K) – 1 kg;
- monopotassium phosphate – 0.2 kg;
- calcium nitrate crystal (15% N + 19% Ca)– 0.7 kg or liquid (7.5% N + 9.5% (Ca) – 1.5 L;
- If there are no micronutrients in the macronutrient fertiliser, 100 mL of micronutrient fertiliser – once a week

Week 9 until the end of September – (1.5 –2 L/plant)

- multi-component fertiliser (<10 % N, 20 %–30 % K) – 1 kg;
- monopotassium phosphate – 0.2 kg;
- magnesium sulphate heptahydrate – 0.2 kg;
- crystalline calcium nitrate (15 % N + 19 % Ca) – 1 kg or liquid (7.5 % N + 9.5 % Ca) – 2 L;

- if there is no micronutrient in the macro-element fertiliser – 100 ml of micronutrient fertiliser – once a week

warm October – (0.5–1 l/plant)

- multi-component fertiliser (<10 % N, 20 %–30 % K) – 1 kg;
- crystalline calcium nitrate (15 % N + 19 % Ca) – 0.5 kg or liquid (7.5 % N + 9.5 % Ca) – 1 L

2) Cultivation of peppers in rings

In the cultivation of peppers in rings, fertilisation is determined on the basis of an analysis of the nutrient content of the substrate. Based on the results of the analysis, it is necessary to determine the fertiliser needs and to apply optimal fertilisation for the cultivated plant.

After planting the seedlings, during the first month, the root system grows beyond the volume of the ring, utilising the nutrients contained in the substrate. During this time, the plants need only be watered with water, and if the growth is weak, specialty compound fertilisers can be used (once about 5 g/ring). When plants in rings placed directly on the ground grow into the substrate, application of the fertilisation to the soil surface, around the ring, and especially in the inter-row should begin. The rules of fertilisation are the same as for traditional (field) cultivation, also regarding fertigation. The spacing of plants and emitters on the line should then be chosen so that one hole is assigned to each ring. Otherwise, the nutrient solution will unproductively drip onto the litter. Capillary systems make it possible to bring nutrients to each plant regardless of the planting method. Fertigation is carried out daily, in an amount of 0.5–1.5 L of medium per plant. In order to test the abundance of the substrate during cultivation, samples of the substrate shall be taken from the ring.

3) Cultivating peppers on straw bales

In the cultivation of peppers using this method, 10-14 days before planting, it is necessary to irrigate the straw bale with water and then add fertilisers to accelerate the fermentation of the straw. Fertilisers for straw are supplied in two doses, at intervals of two days. A single dose of fertiliser per 100 kg of straw is: 1 kg of ammonium nitrate, 0.5 kg of potassium sulphate, 0.4 kg of magnesium sulphate. After the application of fertilisers on the surface of the straw, they should be thoroughly washed with a small stream of water. It is very important to spread fertilisers evenly and wash them thoroughly, as remaining fertilisers on the surface of the bales increase the concentration of salt and cause poor heating of the straw. After 3-4 days, the temperature in the bales should increase. When the temperature in the bale warms up (temp. 40°C and begins to fall, the surface of the bale is covered with a layer of substrate/soil 6-8 cm thick. When the temperature in the bale does not exceed 28 °C (indicating the end of the hot straw fermentation process), generally about 2 days after covering, pepper seedlings are planted. The fertigation begins after the roots have got to the straw. Peppers planted on heated straw very quickly build up green mass and, from plantings established at the beginning of April, enter fruiting early. However, plants planted concurrently with conventional crops show a yield delay due to excessive uptake of readily available nitrogen from the warm substrate and a prolonged vegetative growth phase. The commercial and overall yields are comparable. The principles of top dressing and foliar feeding are the same as in land cultivation.

When growing peppers on bales that are not heated before planting and lack a peat cover, fertigation is introduced with a weak nutrient solution immediately after setting the pepper seedling rings. Irrigation with fertilisation is carried out throughout the entire cultivation period. The food media are prepared according to generally accepted principles. In straw cultivation, 'T-tape' drip lines are used in the following arrangement: 1 line per 1 row of plants.

Example of periodic fertigation on bales with cover (for 1 000 L of nutrient solution)

3–8 weeks after planting – fertilisation every 3–4 days (1.5–2 L nutrient solution/plant)

- multi-component fertiliser (<10 % N and about 25 %–30 % K) – 1 kg;
- monopotassium phosphate – 0.2 kg;
- magnesium sulfate heptahydrate – 0.5 kg;
- calcium nitrate crystal (15 % N+19 % Ca) – 1 kg or liquid (7.5 % N+9.5 % Ca) -21 L;
- If there are no micronutrients in the macronutrient fertiliser, 150–250 mL of micronutrient fertiliser

week 9 until the end of September – fertilisation every 2–3 days (2 –3 L/plant)

- multi-component fertiliser (<10 % N and about 25 %–30 % K) - 1.3–1.5 kg;
- monopotassium phosphate – 0.2 kg;
- magnesium sulfate heptahydrate – 0.5 kg;
- calcium nitrate crystal (15 % N+19 % Ca) – 1.2 kg or liquid (7.5 % N + 9.5 % (ca) – 2.4 litres;
- If there are no micronutrients in the macronutrient fertiliser – 150 – 250 mL of fertiliser
  micronutrient fertiliser

Example of continuous fertigation on uncovered straw

Proportions per 1000 L of medium at a rate of 1.5–2 L per plant per day

- multi-component fertiliser (<10 % N and about 25 %–30 % K) – 1 kg;
- crystalline calcium nitrate (15 % N + 19 % Ca) – 1.2 kg or liquid (7.5 % N + 9.5 % Ca) – 2.4 L;
- if there is no micronutrient in the macro-element fertiliser – 150–250 ml of micronutrient fertiliser

4) Pepper cultivation in sacks

When growing peppers with this method, pre-packaged peat substrates contain all the nutrients sufficient for the first 3-4 weeks of cultivation. The same applies to peat substrate prepared independently (on the same principle as for rings). It is therefore only necessary at this time to irrigate plants daily (0.5 L per day per plant). Permanent fertigation, taking into account systematic calcium and micronutrient fertilisation, is introduced at the time of removal of the first bud. The composition of the nutrient media is the same as for growing in rings, but due to the small thickness of the substrate, the daily dose should not exceed 1 L per plant, otherwise the roots may be flooded (higher doses may be used assuming approx. 15 % drainage of drainage water, with closed fertigation systems). In the summer, the medium is administered 3-6 times a day, from 6:00 to 18:00. From September, it is necessary to limit fertigation to 1-2 times a day and at the same time reduce the amount of medium to 0.5 L/plant.

However, straw beddings are not saturated with nutrients before packaging. Soaking with the medium is carried out the day before planting, using 3-5 L of medium (pH 5.7-6.0; EC 1.8) per bag. Fertigation is introduced 2–3 days after planting. The daily dose of nutrient solution for peppers cultivated on straw sacks is 1–1.5 L per plant (with a 20 % outflow of drainage water the dose should be higher). The frequency of nutrient application is similar to that found in peat substrates. Care should be taken not to flood the substrate during the initial growing period, when the straw is still fresh and fermenting – an increase in its temperature above 35°C causes damage to the roots. Top-dressing fertilisation and possible foliar feeding shall be applied in the same way as in field cultivation.

5) Pepper cultivation in mineral wool

Fertilisation of pepper cultivation carried out in inert substrates occurs through fertigation, supplying the nutrient medium via capillaries to each plant planted on mineral wool mats. The composition of the medium shall be determined on the basis of the nutritional requirements of the peppers at the various stages of development, taking into account the results of the analysis of the water used for irrigation.

Depending on the cultivation period, development phase, variety, etc. the nutrient should contain (in mg/L): 180 - 240 N; 60 - 80 P; 200 - 300 K; 50 - 70 Mg; 170 - 200 Ca; 60 - 100 S; 3 - 5 Fe; 0.7 - 2 Mn; 0.2 - 0.3 Zn; 0.5 - 0.7 B; 0.05 - 0.07 Cu; 0.05 Mo. The optimum pH of the medium is 5.5-6, with EC = 1.7 – 2.3 mS/cm. Foliar feeding, on the other hand, is carried out on the same principles as in field cultivation.

2.4.2. Fertilisation of peppers grown in the field

When establishing a pepper plantation on soils poor in humus, it is grown in the first year after manure, using additional mineral fertilisation in accordance with plant demand. For natural fertilisers, the nitrogen dose of 170 kg N/ha/year (Directive 91/675/EEC) shall not be exceeded. According to the Code of Good Agricultural Practice, the dose of manure with an average nitrogen content of about 0.5 % N should not exceed 35 T/ha. It is also important that solid natural fertilisers are applied within the deadlines specified in the Annex to the Regulation of the Council of Ministers on the 'Action programme to reduce water pollution by nitrates from agricultural sources and to prevent further pollution' (Journal of Laws of 2023, item 244). The optimal time for fertilising with natural fertilisers is early spring; however, for peppers, it is more advantageous to apply manure in autumn, and it should be ploughed immediately after application. On sites with fertile soil, with a high content of humus, it is possible to grow peppers primarily on the basis of mineral fertilisation.

Manure fertilisation can be replaced by using other organic fertilisers, either own (compost) or purchased. The recommended dose of these fertilisers depends on the nitrogen content and must not exceed 170 kg N/ha. Growing catch crops for incorporation is a good solution. As catch crops, the so-called green manures are recommended. These are most often mixtures of leguminous plants, enriching the soil with nitrogen and organic matter, or species with phytosanitary properties, e.g. phacelia. These plants, as green fertiliser, should be incorporated during the autumn of the year preceding the crop.

Peppers are classified as vegetables with high nutritional requirements. **Before starting the cultivation of this species, it is necessary to perform a soil richness analysis and determine fertiliser needs (confirmed by the results of the soil analysis) and apply optimal fertilisation**. An objective assessment of soil can only be conducted after performing the soil chemical analysis. Soil analysis should be performed at District Chemical and Agricultural Stations or other accredited laboratories (accredited in accordance with the Journal of Laws of 2002 No. 166, item 1360, or the provisions of Regulation (EC) No 765/2008 of the European Parliament and of the Council). When determining the dose of fertilisers, the soil type (heavy, light soils) and the exchange sorption of nutrients in the soil should also be taken into account. The optimum soil mineral content for peppers grown in the field should be (mg/dm^3): 90-120 N, 60-80 P, 175-250 K, 50-70 Mg, 600-1200 Ca.

After analysing the soil and comparing it with the presented optimal contents, fertilisation can be decided on. In planned fertilisation, the amount of constituents released as a result of the mineralisation of organic matter introduced into the soil from incorporated green fertilisers, manure, or compost should be taken into account. For this purpose, the so-called fertiliser equivalents for the applied organic fertiliser given in the Code of Good Agricultural Practice should be used.

Forphosphorus and potassium fertilisers in full dose and the first dose of nitrogen fertilisation (in the amount of 30-40 kg N/ha) in pepper cultivation, it is best to apply them in spring, during field preparation for cultivation, mixing the applied fertilisers with a 20-25 cm layer of soil. The rest of the nitrogen is applied as a top dressing in 3 doses. The first dose of top dressing is applied 3-4 weeks after planting, and the remaining 2 doses at intervals of 2-3 weeks. Due to the high sensitivity of peppers to soil salinity, it is best to use high-percentage and chloride-free fertilisers and mix them thoroughly with the arable layer of the soil. Top dressing is preferably done by watering the plants with a solution of fertilisers.

The soil pH plays an important role in the field cultivation of peppers. The optimum pH of mineral soils is between 6.7 and 7.2. If the soil pH, determined on the basis of soil samples, is below the specified range, liming should be applied. The dose of lime needed to deacidify the soil is best determined based on the measured acidity of the soil. The liming treatment should be carried out in autumn or, preferably, in summer, after plants leave the field early, in the year preceding the crop. The effectiveness of liming depends on the good mixing of fertiliser with soil. It is recommended to use calcium fertilisers in carbonate form.

On the other hand, dolomite lime or magnesium lime should be used on magnesium-poor soils. It should be remembered that liming cannot be carried out simultaneously with manure fertilisation, because there is a rapid mineralisation of manure and losses of nitrogen from the soil. **A chemical analysis to determine the soil pH and Ca content must be carried out in the year preceding the crop (in summer or autumn after the plants have been harvested). After receiving the results of the analysis, if necessary, a liming procedure should be performed. Cultivation is also permitted if the determination of the soil pH is carried out in the year the cultivation begins, provided that the soil pH is within the optimum range for the crop.**

Foliar feeding of peppers in the field primarily involves applying calcium fertilisers every two weeks during the flowering and fruit setting period, and potassium fertilisers during the fruit ripening period. Complementary growth promoters can be used to improve the condition of plants and their resistance to adverse climatic conditions. It is also worth trying fertiliser or stimulating preparations that accelerate the ripening of fruits, as the primary factor determining the marketability of field peppers is their colouration.

2.5. Cultivation of soil and preparation for planting

2.5.1. In the field cultivation of peppers

In the field cultivation of peppers, careful and timely implementation of cultivation procedures plays an important role, depending on the condition of the field, the date of planting seedlings, row spacing and plant density. After precursor crops leave the field early, shallow ploughing should be carried out as soon as possible. This treatment will reduce water losses from the soil and cover crop residues or cut straw enriched with mineral nitrogen, which can be an additional source of humus. Shallow ploughing is carried out with a stubble cultivator or a light plough to a depth of 6-8 cm with simultaneous harrowing. After ploughing in the straw, mixtures of leguminous plants as a catch crop for autumn ploughing can be sown. If, on the other hand, no catch crop is sown, then the field should be harrowed as weeds appear. After plants that are harvested late from the field, a cultivator is used. Manure applied in the autumn period should most advantageously be covered with pre-winter ploughing. If green fertilisers are used instead of manure, they should be cut early in autumn and disked to accelerate the decomposition of organic matter. Deep pre-winter ploughing to the full depth of the arable layer is the essential tillage operation performed before the planned cultivation of peppers. If, after plants leaving the field late, no shallow ploughing was carried out or manure was applied for winter ploughing, it is advisable to use a plough with a skimmer.

Spring tillage depends on the type of soil, and it is beneficial to use tillage implements during this period. On dry soil, a unit consisting of a harrow and a cultivator is used, and on cohesive, heavy, and sufficiently moist soil, spring ploughing should be carried out. Cultivation before planting seedlings can also consist of a system of successive treatments, carried out if necessary with different tools, e.g. a drag, a harrow, a cultivator, with simultaneous mixing of fertilisers with the soil. Treatments should be carried out carefully, and the top layer of the soil should be well levelled and loosened in the surface layer. This soil preparation makes it easier to plant seedlings to the same depth. In integrated production, in order to reduce organic carbon losses, the number of cultivation treatments should be minimized, while ensuring that the soil is well prepared before planting.

2.5.2. Peppers under cover in field cultivation

Soil cultivation in facilities, i.e. foil tunnels, which change location on the field annually and where crop rotation can be introduced, will be the same as in field conditions. On the other hand, tall structures that occupy the same place for many years, i.e. wooden tunnels (4-5 years), greenhouses, heated tunnels or modern, unheated steel tunnels, are fixed infrastructure, in which the field cultivation of peppers is often carried out in monoculture. This type of cultivation promotes the multiplication of vascular diseases and causes unilateral use of soil and its impoverishment. In these facilities, soil tillage should be applied for peppers, leaving the soil carefully and deeply cultivated. The depth of the arable layer for peppers must be at least 30 cm; therefore, in the autumn period, it is necessary to perform winter ploughing, and every 4-5 years, subsoiling to a depth of at least 50 cm should be carried out to eliminate the plough pan. Overly compacted soil may contribute to weakening the vigour of roots and aboveground mass. If you plan to grow peppers after using green manure, it is good to keep the soil under vegetation cover for the winter (for example, a mixture of winter vetch and rye), which reduces nitrogen losses, but this only applies to cultivations in tunnels that are free of covers for the winter.

Spring cultivation carried out before planting should ensure proper soil levelling and moisture at the level of 60-80 % PPW.

2.6. Irrigation

An extremely important factor in the success of cultivation is maintaining optimal humidity of the substrate/soil and air, which is achieved through effective irrigation. Peppers have significant and variable water requirements during the growing season. They show the greatest demand for water in the phases of intensive growth and development, flowering and fruiting, and during periods of pronounced water deficit. This species requires the supply of large amounts of water during the growing season, the use of which by plants will depend on the intensity of light, temperature, and air humidity during cultivation. During the period of the highest temperatures, peppers can lose more than 0.5 dm^3 of water per day. In irrigated crops, the size and frequency of irrigation doses depend on the extent of the root system, which is relatively small, and on the intensity of plant transpiration and the rate of water uptake. To produce 1 kg of ripe fruit, peppers consume 60-80 dm^3 of water.

In the field cultivation of peppers under cover, drip irrigation combined with top dressing (fertigation) is most often used. In this type of irrigation, the most common solution is drip lines with emitters built into the walls of irrigation pipes, spaced 20-40 cm apart. Proper placement of emitters, matched to the spacing of plants, allows for very precise determination of solution doses and fertigation control. One pipe should irrigate one row of plants. When mulching the surface, the wires are laid under black foil or straw or on the surface of the non-woven fabric. Peppers are irrigated when the suction force of the soil exceeds 200 hPa (0.2 atm), which can be determined using tensiometers or irometers. In the absence of these devices, the principle should be followed that on light soils it is advisable to use frequent, but small doses of water, whereas on heavier soils the doses may be slightly higher and the frequency of their administration lower (table 3). It is recommended to irrigate peppers in the morning or before noon (May-August 7:00-11:00, September-October 9:00-12:00). In the summer, it is best to administer 2/3 of the hydration dose by 11:00 and 1/3 of the dose in the afternoon (14:00-16:00). In periods of high temperatures, especially during windy weather, it is advisable to mist crops (30-60 seconds, 1-2 cycles per day, between 13:00 and 15:00), as the repeated loss of turgor in leaves and peduncles intensifies the dropping of buds.

Table 3. Indicative doses and frequency of irrigation for peppers under cover depending on the growth phase and type of soil

<table>
<tr><th rowspan="2">Cultivation period</th><th colspan="2">Dose and frequency of irrigation
(L/plant)</th></tr>
<tr><th>Light soils
(at least every 1-2 days)</th><th>Heavy soils
(at least every 2-3 days)</th></tr>
<tr><td>before planting</td><td colspan="2">hydration to a moisture level of 80 % field capacity</td></tr>
<tr><td>immediately after planting</td><td colspan="2">0.5 L/plant (single application)</td></tr>
<tr><td>3-7 days after planting</td><td colspan="2">without irrigation</td></tr>
<tr><td>weeks 2–4</td><td>0.5-1.0</td><td>0.5-1.5</td></tr>
<tr><td>weeks 6–14</td><td>1.0-2.0</td><td>1.0-2.5</td></tr>
<tr><td>15 weeks until the end of September</td><td>1.5-3.0</td><td>2.0-3.0</td></tr>
<tr><td rowspan="2">October-November</td><td>1.0-1.5</td><td>1.0-2.0</td></tr>
<tr><td colspan="2">occasionally unheated facilities, depending on the temperature</td></tr>
</table>

Irrigation of plantations in the field cultivation of peppers is also a very important issue. Although peppers grown in the field tolerate hot days well, during hot and windy weather, they should be monitored for withering. Plantations of this species should be irrigated during periods of water deficit in the soil, as well as during periods of the highest water demand of plants (mentioned above). Therefore, in order to prevent periodic changes in soil moisture, pepper cultivation should be irrigated using, for example, a sprinkler. Irrigation introduced at an early stage of plant development should take place in small (5-8 mm) fine-droplet doses of water. In the later stages of plant development, the periodic loss of water in the soil should be supplemented by irrigating the plantation several times with single irrigation doses (i.e. the amount of water applied per unit area during one irrigation). The amount of a single dose of irrigation depends on: the intended depth of soil wetting, the water capacity of the soil, and its current moisture content. Irrigation of the pepper crop during prolonged drought should be carried out in such a way as to ensure that the soil is adequately moistened to a depth of 30-50 cm. During the year, peppers should receive at least 500 mm of precipitation (rainwater and/or irrigation). In the summer, a single dose should be 200 mm (2,000 m^3 of water/ha).

Water shortages in plantations of large-fruited pepper varieties can also be supplemented by the use of drip irrigation, which also allows fertigation. The drip lines (Ø 16 mm) are arranged in rows next to the plants. The distribution of emitters and the irrigation dose should be adapted to the type of soil, the spacing of plants in a row, and the variety. On light soils, single irrigation doses should be lower than on heavy ones.

Irrigation of field crops of peppers, especially drip irrigation, should be carried out on the basis of measuring instruments (tensiometers, irometers, Watermark probes, etc.). In their absence, one of the simplest ways to determine soil moisture is organoleptic determination – after squeezing a handful of soil, no water flows out, and after opening it, the lump does not disintegrate. This indicates the optimal arrangement of air-water conditions in the soil, which should be at the level of 70-80 % of the field water capacity.

2.7. Care treatments

2.7.1. Cultivation under cover

Cutting of shoots

The most important care procedure is appropriate **cutting and training of plants.** Keeping the main shoot vertical prevents the overturning of plants with a large green mass, and by tying the shoots, spontaneous breaking when loaded with fruits, damage during harvesting, care, and even inspection of the plantation are avoided.

The pepper seedlings are planted into the substrate at a depth no greater than they grew in the pot, while the plant density depends on the cultivation system. It is assumed that for 1 m^2 there should be 9 to 16 main fruiting shoots, so-called leader shoots. In tall facilities, it is therefore recommended to cut 2–4 shoots successively, while in low – 3–4 with cuts limited to 3–4 levels of the crown.

The tying up of the main pepper shoot, and then of each of the leader shoots, can be done with the use of vertical cords attached to the tunnel structure. Then, the shoots should be pinned to the cords with clasps, e.g., ‘tomato’ clasps, so as to minimise the risk of breakage.

An advantageous method, especially in tunnel cultivation, is planting plants in single rows, between horizontal ropes stretched at several heights (the so-called ‘Spanish row’ or sandwich system). The method works best when cutting plants into 2-3 shoots. On both sides of each row of plants, planted every 30–35 cm, tightly spread strings or wires are placed. Brackets for them are 1.5-2.5 m steel posts (Ø 1.5-3 cm) with transverse struts, fastened with ties to the wall of the object perpendicular to the direction of the rows or wooden pegs (Ø 5 cm). The distance between the posts in a row should be 5–7 m. The first level of ropes should be at the height of the main branching of plants, then every 30–40 cm. Shoots growing up to the next levels slips gently between the strings, there is no need to pin them. The advantage of the Spanish row is the full exposure of fruit to light, reduction of mechanical distortions, facilitation of harvesting, care treatments and plant protection. Good ventilation of rows and reduction of humidity in the crown atmosphere reduces the risk of plant infestation by diseases and limits the occurrence of pests, thereby reducing the use of plant protection products. In order to maintain even fruiting of such plants, the peppers should be cut every two weeks.

The rules for cutting shoots are always the same:

- removing the buds from the main branching ('walnut' phase),
- derivation of 2–4 of the strongest shoots that will act as leader shoots;
- depriving the leader shoots of the excess of vegetative and generative parts (one leaf, buds, a section of the side shoot with the leaf is left in each knot)
- above 8–10 knots on the leader shoot, there is left a side shoot of the first row, fruiting similarly to the leader shoot, with one leaf and a leafy fragment of the side shoot of the second row.
- removal of leaves and shoots from the main shoot;
- the topping of the plants above the grown but still immature fruit (approx. 1.5 months before the planned end of cultivation).

A cut limited to as many nodes as there are leader shoots must be used in wooden tunnels and foil tunnels. This will prevent the fruit from jamming between shoots and overloading young plants. The natural crown, remaining above the last level of a cut, will serve as a thermal cover on cold nights and as a natural shade cloth that protects the fruit from sunburns. Successively cut peppers are stimulated to set new fruit, which quickly reaches the appropriate size and colour, maintaining the shape. During cultivation, however, it is necessary to remove barren shoots from the inside of the crown. Throughout the growing period, damaged parts of plants, ageing lower leaves, and basal shoots should also be removed.

Mulching of crops

The surface of the ground under cover shall be mulched with black polyethylene foil or black crop cover with a weight of at least 50 g/m^2. The exception is greenhouse crops from the earliest plantings, where white foil is used to increase light diffusion or for sanitary reasons. Biodegradable mulches (paper, starch foil) or organic mulches (straw, cuttings of leguminous plants) can also be used to mulch the crop. Mulching reduces the evaporation, development of weeds, pests and certain diseases, which leads to a reduction in the number of chemical treatments.

Introduction of pollinators

Peppers are self-pollinating and mechanical or chemical pollination does not yield results. The use of natural pollinators – bumblebees – does not increase the yield, but only affects to some extent the shape and weight of the fruit. The presence of bumblebees in facilities under cover may increase the number of pollinated flowers, but it does not guarantee a greater number of buds retained on the plant. Even fertilised flowers and buds are very sensitive to climatic stresses causing them to fall. Fruits from flowers pollinated by bumblebees, however, have more seeds, resulting in a better shape and greater weight.

However, not all varieties will respond equally positively. Bumblebees cannot withstand temperatures >30°C and poorly tolerate high humidity, so their efficiency increases with higher and better-ventilated cultivation facilities. A beehive with 40 workers is sufficient for an area of 500 m^2. The lifespan of bumblebees in tunnels is slightly longer than in greenhouses due to the possibility of insects migrating outside the facility and utilising natural resources. However, their proximity and attractiveness (e.g. red clover) may result in the complete abandonment of pepper flights in the tunnel.

Controlling the temperature inside the building

Airing of the crop should be done gradually. First, vents are placed high (roofs in greenhouses, top gables in tunnels), and only when necessary side and top air vents. During the spring and autumn cold season, it is advisable to install approximately 80-centimetre-high foil covers on the tops of tunnels. This prevents the overcooling of young plants and allows air to be exchanged over them. However, peppers are very sensitive to the drying atmosphere of intense air movement; they quickly wither and shed their buds. During strong winds (especially in hot weather), the vents should be open only from the leeward side. The best way to supplement the shortage of water in leaves and buds is short-term (about 4 minutes) misting or irrigation of plants. On hot, windless days, this treatment not only increases humidity, but also reduces the temperature of leaves and air under the covers.

Shading is a way of lowering the temperature and protecting against excessive radiation. External shading of the object should be used only in the period from May to July. Later, when the intensity of light decreases and the plants are well nourished with nitrogen and calcium, the risk of uneven colouring of the fruit increases. On the other hand, that is when the most fruit burns occur. If the facility is not equipped with movable shade cloths, it is necessary to cover the coatings very accurately with a thin layer of a specialised shading preparation or chalk solution. In greenhouses, heated tunnels, and high, modern unheated tunnels equipped with internal shade cloths, these should be drawn on the hottest days and cold nights, as they will then serve as thermal insulation curtains.

In tunnel cultivation of peppers, not only multi-seasonal foils should be used, but also those with additional qualities to prevent rapid temperature fluctuations (thermal foils), increase light scattering, and prevent steam condensation and drops from falling on the leaves (anti-fog).

2.7.2 In the field

Care treatments in the field cultivation of peppers consist of combating weeds, loosening the soil between plants, fertilising them, and irrigating during drought. Pepper, as it grows and develops, is a plant with stiff stems and does not propagate very strongly; therefore, in field cultivation, it does not require cutting, guiding at supports, or binding.

The treatment that improves the moisture and thermal conditions of the soil in the cultivation of peppers, as well as limits weed growth, is mulching. For mulching, black foil can be used a few days before planting, for example. After planting the seedlings, once the soil has been properly heated, the inter-rows can be mulched with sawdust, bark, or chopped straw (straw cut into short pieces).

It is also good practice to remove infested fruits, which are a source of pathogenic infections, as well as dwarf fruits that limit the vigour of plants. The size of the fruit is also positively affected by the removal of the first fruit. However, this treatment is not necessary – it may slightly delay the first harvest.

2.8. Selection of varieties

Choosing a fertile variety resistant to adverse climatic conditions and pathogens is one of the most important factors in integrated vegetable cultivation. Almost all recommended varieties of peppers adapt well to various types of covers, and some are suitable for both tunnel and field cultivation. Due to the strength of growth, some of them are particularly suitable for growing in low tunnels. Other varieties, which yield well in tunnels, are recommended for cultivation in greenhouses due to their very even fruit setting on all levels. The worse the growing conditions, the more tolerant the varieties should be to physiological disturbances such as blossom end rothttps://pl.wikipedia.org/wiki/J%C4%99zyk_angielski, coloured (brownish) fruit (Cf), or stip.

The selection of varieties must also be adapted to the market requirements. Due to the fact that the largest area in Poland is occupied by pepper cultivation in unheated tunnels, the assortment of varieties is selected in terms of yield potential, fruit quality, early fruiting, fast colouring rate, and resistance to pathogens. Consumer habits determine the dominance of varieties with cuboid-shaped fruits (block type) and red colouring (especially dark red). Weaker preference is given to yellow, orange, green, and white fruits and cone-shaped fruits (e.g. kapia type, igołomska type, Dulce Italiano type). The demand for purple, navy blue, and brown fruits, as well as other shapes (so-called topepo tomatoes, miniature conical and spherical), is very small, which is why they are practically not found in cultivation. It is also rare to grow hot peppers due to the low demand of the retail market and the insufficient biological value of the raw material for processing in our climatic conditions.

The preferences of retail and wholesale customers regarding the size and shape of the fruit also differ significantly. The wholesale market for fresh vegetables requires fruit with a characteristic shape for a given segment of varieties corresponding to European standards required for network trade and export. Retailers, sourcing from commodity exchanges and marketplaces, accept misshapen fruits on the condition of their large weight, thick skin, and excellent colouring. For processing, the fruit must be properly coloured and healthy (whole from field crops, cut from under cover).

The decision to select a variety for cultivation should be made specifically with regard to the requirements of the recipient market, taking into account their yield potential, the rate of growth and colouring of the fruit, and resistance to infectious diseases.

In field crops, the largest acreage is occupied by Polish, red-fruit varieties of the block type, characterized by a rigid, short main shoot and very rapid fruit setting, which limits their vegetative mass. Thanks to this, they are not prone to overturning under the weight of the fruit or in the case of strong winds. There is no need to stake them. They also endure a moisture deficiency in the soil and are relatively resistant to blossom end rot of the fruit. Large-fruited varieties are also suitable for cultivation in open ground.

The necessary information on the varieties of peppers that can be grown in the IP system is provided on the website of the Research Centre for Cultivar Testing (COBORU) under the tab 'Selection of varieties for integrated plant production' (https://www.coboru.gov.pl/pdo/ipr).

2.9. Physiological disorders

Environmental factors such as temperature, water, light, and nutrient content have a significant impact on plant growth and development. However, both excessive and limited influence of a specific factor cause a number of disturbances in plant metabolism, preventing the use of its full yield potential. Physiological changes in the appearance of plants that may occur as a result of the adverse effects of the aforementioned factors are classified as non-infectious diseases (physiological disorders). Due to the fact that the occurrence of physiological disorders is often the result of a combination of many factors and without a detailed analysis of the growing conditions, it is difficult to determine their cause, it is important to know the crop requirements of plants and to systematically carry out monitoring of plantations in order to correctly recognize disease symptoms. Symptoms of non-infectious diseases, especially deficiencies of components in the form of discolouration or distortion, manifest themselves on the youngest leaves – smaller than half the normal size – or on the oldest ones. Then, respectively, they move downwards or upwards on the plant and are visible on well-formed leaves. Simultaneous occurrence of homogeneous symptoms in most plants or a large number of clusters of plants with similar changes, absence of mycelium in the damaged areas or of insects or mites, will indicate the effect of non-infectious factors on the plant. The consequence of the occurrence of this type of disease is, in addition to visible changes in growth and development, limited yield and a decrease in the quality of pepper fruits.

The most common symptoms of physiological disorders (non-infectious diseases) appearing during the period of growing peppers under cover and in the field are listed below.

CHLOROSIS AND YELLOWING OF LEAVES

Reason: accelerated degradation of chlorophyll and ageing of the lower leaves due to nitrogen deficiency or abnormal uptake.

Counteracting: monitoring the health status of the root system and conducting a substrate/soil analysis – in the event of root damage – identifying the cause and eliminating or mitigating the harmful biological factor (application of plant protection products) or climatic factor (enhancement of air-water conditions in the substrate/soil). In the case of nitrogen deficiency, application of soil fertilisation to plants using available nitrogen fertiliser.

Reason: limited or inhibited synthesis of chlorophyll due to magnesium deficiency and micronutrients, i.e., manganese or molybdenum – changes in the leaves of the central and apical parts of plants; damage to the iron absorption mechanism - chlorosis of the apical leaves.
Counteracting: verification of the physiological condition of roots and soil pH (pH) - improvement of air-water conditions in the substrate/soil, application of fertiliser acidifying the substrate/soil to the roots, drying of excessively moist substrate, foliar feeding with multi-component micronutrient fertiliser with magnesium.

Reason: in conditions of luxurious nutrition with nitrogen and calcium, at low light intensity and/or temperature >30°C, precipitation of calcium and/or magnesium oxalate in leaves.
Counteracting: root and foliar feeding with calcium preparations and fertilisers containing as little nitrogen as possible.

Reason: physiological chimera with a genetic basis, spontaneous genetic mutation occurring in the plant - leaf variegation.
Counteracting: use high-quality seed material for sowing during the period of seedling production.

LEAF NECROSES
Reason: disturbed water and nutrient management (potassium deficiency in the leaves), final phase of chlorosis of the leaves.
Counteracting: leaf sampling and analysis of plant material, application of compound fertilisers and/or growth promoters.

LEAF DEFORMATIONS

a) ***Bubble-like surface of leaf blades at the top of the plant, sharpened angles of apical leaf blades.***

Reason: deficiency of micronutrients, especially zinc, with increased soil pH (pH above 8).

Counteracting: assessment of the condition of roots and soil pH – improvement of air-water conditions in the substrate/soil, root application of soil-acidifying fertiliser, foliar feeding with zinc-containing micronutrient fertilisers.

b) ***Leaf dwarfism***

Reason: potassium deficiency, disturbed water and nutrition management of plants.

Counteracting: regulation of air-water conditions in the substrate/soil, foliar feeding with micronutrient and potassium fertilisers.

c) ***Leaf nervation***

Reason: hormonal disorders, e.g. due to the use of excessively high concentrations of organic growth promoters.

Counteracting: use of appropriate doses of growth stimulants, as recommended by the manufacturer.

BRITTLENESS OF SHOOTS, PETIOLES, AND STALKS

Reason: excessive potassium nutrition.

Counteracting: reducing the amount of potassium or increasing the amount of nitrogen and calcium in the medium, or applying nitrogen fertiliser to the roots, sprinkling nitrogen fertiliser (e.g., calcium nitrate), foliar feeding with nitrogen fertiliser – especially before the fruit ripening period.

FALLING OF FLOWERS AND BUDS

Reason: any stressful climatic conditions: too low (below 17°C) or too high (above 30°C) air temperature, too low air humidity and excessive transpiration (drought, wind), inadequate air-water conditions in the substrate/soil and air.

Counteracting: elimination/reduction of a stress factor adverse to plants.

Reason: excessive nitrogen nutrition, high temperature and humidity - excessive vegetative vigour of plants.

Counteracting: reduction in the amount of nitrogen or increase in the amount of potassium in the medium (or root application of potassium sulphate by sprinkling), reduction in humidity and temperature - intensive ventilation of cultivation facilities.

FRUIT DEFORMITIES

d) ***Very large fruit, multi-chambered, concave bottom of the pericarp, poorly developed placenta and seeds, so-called king fruit***

Reason: fruit setting at an air temperature below 17°C.

Counteraction: elimination of a stressor – increasing/decreasing temperature in cultivation facilities.

e) ***Fruit large, very numerous chambers, slightly flattened in the vertical axis, undeveloped***
placenta, no seeds

Reason: fruit setting at an air temperature above 30°C.

Counteraction: elimination of a stressor – increasing/decreasing temperature in cultivation facilities.

f) ***Internal or external chambers (placental proliferation)***

Reason: setting fruit at temperatures outside the optimal range (17.5–30°C), especially during periods of low light intensity.

Counteraction: elimination of a stressor – increasing/decreasing temperature in cultivation facilities.

g) ***Fruits small, matte, with rounded apex***

Reason: variable nutrient uptake under temperature fluctuations, resulting in periodic physiological drought.

Counteracting: increasing the amount of irrigation doses until fruit of the correct shape is obtained.

h) ***Fruits elongated with concave lateral surface, slow colouring***
Reason: excessive nitrogen nutrition.
Counteracting: corrective improvement of plant nutrition in terms of proper balance of ingredients - increase the amount of potassium in the medium by 10-30 %, foliar feeding of plants with potassium-phosphorus fertiliser.

FAULTY COLOURING OF FRUIT

i) ***Green spots on the coloured fruit***
Reason: precipitation of calcium and/or magnesium oxalates in fruit with luxurious nitrogen and calcium nutrition at low light intensity and/or temperature above 30°C.
Counteracting: limiting the vegetative mass of plants, removing barren shoots, proper care (pruning)/training of plants, increasing the dose of potassium (K) by 20 %.

j) ***Purple streaks on uncoloured fruit, disappearing during ripening***
Reason: cold stress during the fruit maturation period.
Counteracting: foliar feeding with stimulators regulating the symptoms of cold stress in plants.

k) ***Bleaching of the rind on the fruit - 'bar code' (symptom accompanying leaf variegation)***
Reason: physiological chimera in unsuitable climatic conditions night/day, e.g. low temperature at night after a long period of low-intensity light during the day.
Counteracting: using high-quality seed material for the production of seedlings.

l) ***Local, significant brightening of the coloured fruit***
Reason: degradation of the periwinkle at the point of internal damage to the fruit, presence of a pest foraging inside the fruit.
Counteracting: control, assessment and appropriate protection against plant pests.

m) ***Staining in the area of damage***
Reason: increase in the secretion of endogenous ethylene in response to tissue damage in blossom end rot or by a pest developing inside the pericarp (fungi, pests), acceleration of colouration as a result of fruit ageing.
Counteracting: prevention of blossom end rot, pest control, and the use of pepper plant protection products in accordance with the relevant plant protection programme.

DAMAGE TO FRUIT

n) ***Brown spots on the lateral surface of the pericarp or on the tops of young fruits; dry*** - in low humidity conditions, ***swollen -*** in high air humidity
Reason: calcium deficiency in fruits, the so-called blossom end rot of fruits occurring during the formation of buds.
Counteracting: maintaining even, optimal substrate/soil humidity at 60-80 % field capacity and air (60–80 %), preventive spraying of buds and very young fruits with calcium preparations.

o) ***White-cream dry spots, parchment-like - in low humidity conditions, loosened*** - at high humidity
Reason: sunburn.
Counteracting: appropriate vegetative development of plants before the maturation of the first fruits - proper pruning and training of pepper plants, carried out at the right time, shading of cultivation areas.

p) ***Open chambers, visible bearing***
Reason: damage to buds in the early vegetation phase by pests/sun.
Counteracting: maintaining an even, optimal soil/substrate humidity of 60-80 % PPW and air of 60-80 %, adjusting the size of irrigation doses, introducing adequate protection against pests.

q) ***Fractures of pericarp***
Reason: large, short-term fluctuations in the humidity of the substrate/soil and air, especially during periods of low temperatures - high humidity at night, low during the day.
Counteracting: maintaining an even, optimal humidity of the substrate/soil at 60-80 % of field capacity and air at 60-80 %, adjusting the size of irrigation doses.

FRUIT SKIN BLEMISHES AND DISCOLOURATIONS
Reason: periodic fluctuations in the moisture content of the substrate/soil and air, with a potassium deficiency in the fruit.
Counteracting: maintaining an even, optimal humidity of the substrate/soil at 60-80 % of field capacity and air at 60-80 %, adjusting the size of irrigation doses.

WILTING OF PLANTS
Reason: disturbed water management - excessive transpiration - in conditions of very low air humidity (drought, intense wind) or substrate/soil (limited water uptake), root infestation by soil pathogens, mechanical or chemical damage to the root system.
Counteraction: identification of the type of root damage – increasing the water dose in case of partial root damage in the substrate/soil - poorly or moderately moist, normalization of air-water conditions in the substrate/soil.

INHIBITED GROWTH
Reason: substrate/soil temperature after planting below 10°C, air temperature after planting below 1°C or above 30°C, deficiency or incorrect uptake of nutrients – mainly nitrogen, root system damage due to inadequate substrate/soil moisture and/or mechanical damage, excessive number of fruits on the plant.
Counteracting: early stretching of foil on wooden and blocked tunnels, planting plants after stabilization of thermal conditions – at least to the lower end of the optimal range, foliar treatments with fertilisers and growth stimulators containing phosphorus. In case of a decrease in vigour at air temperatures above 15°C, application of foliar feeding with nitrogen (N). If the results of the analysis of the collected plant material show irregularities in the

mineral content, a multi-component foliar fertiliser should be applied as soon as possible, at the lowest concentration recommended by the manufacturer. This will improve the functioning of the plant before it appropriately responds to nutrition based on the results of the chemical analysis of the substrate/soil.

III. PROTECTION AGAINST HARMFUL ORGANISMS

Harmful organisms, i.e. pests (pathogens, weeds), always occur, even in fields in very good condition and carefully prepared for sowing or planting, which is why protection against them is an important element of integrated vegetable production. Integrated production is a modern and developing cultivation system that takes into account the expectations of customers in relation not only to attractive-looking fruits, vegetables, and other agricultural products, but also to products of high quality. It allows for the production of crops with the highest biological and nutritional values, which are safe for human health. Plant products are strictly controlled for residues of plant protection products, fertilisers, and other substances hazardous to health. Without effective regulation of the level of threat from pests, it is difficult to obtain a high yield of good quality, while maintaining the profitability of production. The intensification of agricultural production poses a significant threat to the surrounding nature, which is why environmental protection is an important issue. Integrated production also takes into account ecological objectives such as the protection of the agricultural landscape and biodiversity.

Chemical protection of pepper against pests should be carried out in accordance with the principles of Integrated Plant Protection, as required, inter alia, by the relevant European Union directives (e.g. Directive 2009/128/EC, Directive 2019/782) and the Plant Protection Products Act of 8 March 2013, (consolidated text: Journal of Laws of 2024, item 630). Plant protection products currently registered in vegetable crops are subjected to thorough testing, in accordance with the rules laid down by the European Union. Stringent requirements as regards the quality of the measures, their toxicology and effects on arable crops and the environment make sure that the recommended measures do not pose a risk to the natural environment, the user or the consumer, provided that they are properly applied.

The general principles of integrated plant protection include: 1. preventing the occurrence and multiplication of harmful organisms or reducing their negative impact; 2. monitoring the occurrence of harmful organisms and, on the basis of these observations, making decisions on the implementation of plant protection treatments; 3. combating harmful organisms. In integrated production, efforts should be made to minimize the potential pest risk as much as possible, primarily using agrotechnical, biological, mechanical, and physical methods, with the chemical method serving as a supplement.

Prevention plays a very important role in counteracting harmful organisms and eliminating their negative effects. Care should be taken to create optimal growth conditions for crops and maintain them in good condition, as only such plants are more resistant to pests. This can be achieved through appropriate crop rotation, proper agrotechnics and careful soil cultivation, the use of resistant or tolerant varieties and healthy seed and planting material, the use of balanced fertilisation and irrigation, the prevention of the introduction of harmful organisms, the protection and creation of favourable conditions for the presence of beneficial organisms, and the application of phytosanitary hygiene rules.

Mechanical soil cultivation plays a significant role in the control of certain pest species and reduces the number of viable weed seeds. All cultivation operations prior to planting should be carried out carefully, taking into account the current state of the field and in a timely manner. Appropriate planting dates and row spacings and plant densities should be chosen so that protection by non-chemical methods is possible and the use of chemicals can be kept to a minimum.

The list of plant protection products authorised for use in Poland is published in the register of plant protection products on the website of the Ministry of Agriculture and Rural Development. Up-to-date information on the use of pesticides in individual crops is included in the labels of products available on the Ministry of Agriculture and Rural Development website: https://www.gov.pl/web/rolnictwo/etykiety-srodkow-ochrony-roslin. Information on plant protection products is also included in the protection programmes available on the website of the Institute of Horticulture - National Research Institute, at the following address: http://arc.inhort.pl/serwis-ochrony-roslin. A tool to assist in selecting pesticides for arable crops is the search engine for plant protection products, available on the website of the Ministry of Agriculture and Rural Development, at the address: https://www.gov.pl/web/rolnictwo/wyszukiwarka-srodkow-ochrony-roslin.

The list of plant protection products approved for integrated production is prepared by the Institute of Horticulture - National Research Institute in Skierniewice and published on the Institute's website at: http://www.inhort.pl/serwis-ochrony-roslin, and is also available through the Pest Alerting Platform, published on the website of the Institute of Plant Protection – National Research Institute in Poznań, at the following address: https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.

Only products authorised in Poland for marketing and use, which clearly indicate on the labels attached to the packaging that they are recommended for the species at hand, may be used for protection against pests. With regard to the registration of plant protection products, there are differences between Poland and the countries of the European Union; therefore, when choosing preparations for the procedure, it is not permitted to follow recommendations from other countries. Herbicides should be used in accordance with the recommendations given on the label Treatments should be performed under optimal conditions for the action of the applied agents in order to make maximum use of their biological activity, while minimizing doses, so as not to endanger human health, animals, or the environment. **Plant protection products with different mechanisms of action should be used alternately (where possible) to prevent pest resistance to pesticides.**

For ecological and economic reasons, the number of treatments should be limited to the minimum necessary and plant protection products should be used in the lowest possible doses, ensuring sufficient effectiveness. This reduces pressure on the natural environment and protects the biodiversity of the agricultural environment. **Principles of integrated plant protection must be respected and preference should be given to any non-chemical means of reducing and eradicating pests (pathogens, weeds). At least one of the plant protection treatments performed should be carried out with a non-chemical preparation (where possible).** Reducing the use of plant protection products can be achieved by: reducing doses, applying the split dose method, reducing the number of treatments by adjusting the timing of treatments to the developmental stages of pests when they are most sensitive, as well as adding adjuvants to the spray liquid, selecting appropriate and technically efficient spraying equipment, and adjusting the amount of water used for the treatment, depending on the pests to be controlled.

One way to reduce the use of plant protection products may be to apply them precisely in locations where a specific harmful organism is present. When controlling some pests, it is not always necessary to spray the insecticide on the entire plantation; sometimes, based on accurate identification, it is enough to perform the operation on the edges or selected parts of the field. Some species of weeds (e.g. couch grass) may not grow in a uniform way on the entire surface of the field but in the form of patches. In this case, spraying can be limited only to their places of occurrence.

Pests do not necessarily occur annually and on every plantation, so not all species require equal control. The basic principles of Good Plant Protection Practice include the application of agents based on the correct identification of pests and their current prevalence, taking into account the available pest thresholds, rather than according to a predetermined programme. It is therefore very important to carry out systematic inspections of pepper crops for the presence of harmful organisms, determining their severity and area of occurrence, as well as forecasting the occurrence of weeds. Various types of traps are currently used to catch insects, utilising the insects' ability to respond to light wavelengths and various types of odours. Knowledge of inspection methods and the ability to identify pests or symptoms of damage caused by them are essential for alerting. In the event of difficulties in identifying pests, specialists should be contacted who, in addition to identifying the harmful organism, may also recommend an appropriate method to control it.

Not all plant protection products intended for use in the cultivation of a particular species should be used in integrated production. First of all, it is necessary to use those agents that have the shortest withdrawal period and have the least negative effect on beneficial organisms. To perform the procedure, it is necessary to choose measures that may cause the least possible side effects on human health and the environment, and to use them in a way that reduces the risk of resistance in harmful organisms. For reasons of environmental protection and the need to ensure the preservation of biodiversity on the plantation, the annual use of the same active substances and chemical groups should be avoided, as this may cause weed compensation or the emergence of resistant biotypes.

The effect of plant protection products on harmful organisms depends not only on their species composition, or the crop and its development phase, but also on soil and climatic conditions. Some products may be used for prevention (e.g. fungicides) or intervention (pesticides and herbicides). Herbicides should only be used in phases of the highest sensitivity of weeds and in doses carefully adjusted to the soil conditions. Better efficiency and more economical consumption of some products can be obtained by adding adjuvants to the liquid. These additives reduce the surface tension of the usable liquid, increase the adhesion of agents, improve penetration into the plant, and limit leaf washing. Herbicides generally work more strongly the higher the temperature, while some insecticides may act adversely or cause damage to the sprayed plants. It is recommended to spray the plantations during rainless and preferably windless weather, when the air temperature is 10-20°C. If the temperature is higher, treatments must be carried out in the early morning (when the plants are in full turgor) or in the afternoon.

Treatments are best done with sprayers that provide exact coverage of the sprayed surface with utility liquid droplets equipped with low-pressure, flat fan atomisers. As a rule, it should be assumed that vortex atomisers should not be used on standard field beams due to the impossibility of obtaining an even distribution of liquid. This is due to the conical shape of the spray jet and the narrow spraying angle.

The usable liquid should be prepared in a quantity not greater than necessary for use on the sprayed surface. Rinse emptied packaging three times with water and pour the remaining liquid into the spray tank. The most commonly recommended amount of liquid using conventional sprayers is 200-300 L/ha for soil herbicides and 150-250 L/ha for foliar herbicides, and using the AAS technique (auxiliary air stream) 100-150 and 75-150 L/ha respectively. For the application of fungicides and insecticides using conventional equipment, 200-400 L/ha should be used when spraying plants up to a height of 25 cm or until row closure, and 400-600 (800) L/ha when spraying taller plants or after row closure, with AAS 100-150 and 150-200 (400) L/ha respectively. Attention should also be paid to the detailed recommendations contained in the label of the product, which must be followed.

The speed of movement of the sprayer should be determined by the wind speed during the treatment. For a sprayer without an auxiliary air stream, the speed of its movement shall not exceed 4-5 km/h at a wind speed of more than 2 m/s; while during favourable weather (wind up to 2 m/s) – 6-7 km/h. Sleeve sprayer and AAS can move at a speed of 10-12 km/h.

After treatment, the sprayer should be thoroughly washed, preferably with special agents designed for this purpose, made on the basis of sodium phosphates or hypochlorite. Washing the sprayer should be carried out on a pre-prepared Biobed or the rinsate should be collected and poured into the sprayer tank, and then used on the treated surface. During work in the storeroom of materials, during the preparation of the usable liquid, performing treatments, and washing the sprayer, it is absolutely necessary to comply with health and safety regulations and use appropriate protective clothing.

Plant protection products differ in their length of action and persistence in the environment. This should be taken into account when planning follow-up crops or for screening, when the plantation (e.g. destruction by diseases or pests) shall require earlier liquidation for any reasons.

In greenhouses, an effective method of pest control is fumigating empty growing rooms by burning sulphur after harvesting. For this purpose, sulphur is burned at a dose of 15 g/m^3. For 1 kilogram of sulphur, 40 grams of potassium nitrate should be added. The gassing time is 12-24 hours. The temperature in the greenhouse during gasification should be 15-30°C.

In crops under cover, disinfection of the substrate can be carried out – thermal disinfection with steam using special steam generators, which is introduced to a depth of 20-30 cm. In order for the treatment to be effective, the ground temperature should be maintained at 90-100°C for 20-30 minutes. By disinfecting the substrate, wireworms, grubs, cutworms, crane fly larvae, leatherjackets, as well as root-knot nematodes and other phytophagous soil nematodes are combated. Under cover, before cultivation begins, the soil can also be mulched with black polyethylene foil or non-woven fabric to limit weed growth.

It is important to comply with the rules of phytosanitary hygiene. Attention should be paid to the careful collection of plant debris after the end of the season, as they can be a place for wintering harmful organisms. This applies to both field crops and those grown under cover. It is important to establish a crop from healthy seedlings, not infested by pathogens and pests. Some pests can inhabit plants very early at the stage of seedling production, with which they are then brought to the place of cultivation. Systematic cleaning of vehicles, machines, and tools used for plant care during cultivation prevents the transmission and further spread of pests.

Plant protection products should be used according to the recommendations provided on their labels and in a way that does not create risks to human and animal health or to the environment

3.1. Weeds

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Pepper is a species that competes poorly with weeds for habitat factors. Weeds growing up to ½-¾ of the plant height can reduce light intensity by 20-40 %, depending on the degree of infestation, thereby worsening the growing conditions of the crop. The competition of weeds is particularly harmful during the periods of flowering, fruit development, and harvesting, as it causes the fruits to have weaker and slower colouration.

As a result of weed infestation, there may be periodic excessive humidity after irrigation or rainfall. Weeds also reduce the temperature of the soil, which in combination with high humidity promotes peppers being stricken by diseases. Peppers should be kept free of weeds from planting at least until the first 2-3 harvests, and in cultivation under cover even until the end of August. In field cultivation, peppers can tolerate weeds up to 5–6 weeks after planting, provided that they are later weeded out. Weeds appearing before and during harvesting, referred to as ‘secondary weeding’, are also problematic, as they make harvesting difficult, delay the ripening of the fruit and reduce yields.

The timing of planting peppers coincides with the period of spring, mass emergence of weeds (table 4). Couch grass may occur if it has not been effectively destroyed in the precursor crop or after its harvest.

In field crops of peppers, the weeds mainly consist of annual monocot and dicot species, and perennial species may also appear, e.g. couch grass. The dynamics of the emergence of individual species depends, among other factors, on the stock of seeds in the soil and weather conditions. The most dangerous weeds in the field cultivation of peppers include species such as: potato weed, white goosefoot, redroot pigweed, and cockspur grass. These species, apart from white goosefoot, require higher average temperatures for germination and emergence which is why they are commonly found on plantations. Often, there are also such species of weeds as: common chickweed, buck-bindweed, white dead-nettle, purple dead-nettle, field mustard, shepherd’s purse, groundsel, field pennycress, annual nettle, false mayweed, black nightshade, field pansy. They already germinate at lower temperatures, but appear en masse in pepper crops together with thermophilic species. Less frequently, there may be: small-flowered crane’s-bill, common fumitory, common stork’s-bill, catchweed, Persian speedwell, redshank, and of monocot species: foxtails, annual meadow grass, wild oat.

Many weed species have a very broad ’ecological optimum’, i.e. they can appear at different times of the growing season, from spring to harvest, regardless of weather conditions. These include, among others: white goosefoot, field mustard, potato weed, shepherd’s purse, field pennycress, field pansy, common stork’s-bill, Persian speedwell. Secondary weeding, which occurs just before or at the time of harvest, is much less harmful than primary weeding, but delays the ripening of the fruit, makes it difficult to carry out treatments against diseases and pests, and makes harvesting very difficult.

In cultivation under cover, thermophilic species can appear en masse, including redroot pigweed, cockspur grass, potato weed, and common chickweed, which can pose a significant problem as it can develop even during low temperatures when these structures are not heated. Under cover, especially in high polytunnels, weeds grow faster than in uncovered ground and are more dangerous. Weeding should be reduced even in the period before the tunnels are set up, paying particular attention to the destruction of perennial, deep-rooting weeds. This is especially true of couch grass, which can be destroyed by recommended agrotechnical methods or chemical agents, using non-selective agents with systemic action. In field cultivation, couch grass and other weeds are best destroyed with non-selective herbicides with systemic action in the summer-autumn period, in the year preceding the cultivation of peppers.

Currently registered herbicides undergo thorough testing, in accordance with the rules set by the European Union. Strict requirements regarding the quality of the products, their toxicology and the impact on crops and the environment ensure that the measures recommended in vegetables do not pose a threat to the natural environment, the user and the consumer. It is worth noting that herbicides included in the selection for vegetables, like other agents, do not exhibit harmfulness, provided that they are properly used in accordance with the approved label. Observing the instructions for use, such as the right choice of agent, the dose rate, the date of application, appropriate development phases of the crop and weeds, technical conditions of the procedure and other factors, determines the safety of treatments with all plant protection products.

Table 4. Harmfulness of major weed species for peppers in field cultivation

Species – English and Latin name	Harmfulness
1. Dicot weeds	
Geranium (*Geranium* spp.)	**+**
Common fumitory (*Fumaria officinalis* L.)	**+**
Pansy (*Violas* spp.)	**+**
Field mustard (*Sinapis arvensis* L.)	**++**
Common chickweed (*Stellaria media* (L.) Vill.)	**+++**
Common stork's-bill (*Erodium cicutarium* (L.) L'Hér.)	**+ (++)**
Dead-nettles (*Lamium* spp.)	**++**
White goosefoot (*Chenopodium album* L.)	**+++**
False mayweed (*Matricaria maritima* L. subsp. *inodora* (L.), Dostál)	**+**
Annual nettle (*Urtica urens* L.)	**+ (++)**
Catchweed (*Galium aparine* L.)	**++**
Buck-bindweed (*Fallopia convolvulus* (L.) Á. Löve)	**++**
Field horsetail (*Equisetum arvense* L.)	**+**
Groundsel (*Senecio vulgaris* L.)	**++**
Redroot pigweed (*Amaranthus retroflexus* L.)	**++**
Shepherd's purse (*Capsella bursa-pastoris* (L.) Medik.)	**+++**
Field pennycress (*Thlaspi arvense* L.)	**++**
Potato weed (*Galinsoga parviflora* Cav.)	**+++**
2. Monocot weeds	
Cockspur grass (*Echinochloa crus-galli* (L.) P. Beauv.)	**+++**
Couch grass (*Agropyron repens* (L.) P. Beauv.)	**++**
Foxtails (*Setaria* ssp.)	**+**

(+++) very high harmfulness; (**++)** high harmfulness; (**+)** low harmfulness or a locally important weed

Note! Proper protection against weeds requires knowing weed species and methods of their control. **It is the responsibility of every IP producer to identify the species present in the field designated for pepper cultivation and to record their names in the integrated production notebook.** Observations should be carried out in the year preceding the cultivation of pepper, and for proper recognition of weed species, one can use the Integrated Pepper Protection Methodology, which contains photographs of weeds in various developmental phases, as well as atlases of weeds, guides or special applications with numerous photographs of weed species. The methodology is available on the website of the Institute of Horticulture – National Research Institute in Skierniewice at: (http://arc.inhort.pl/serwis-ochrony-roslin/metodyki/metodyki-rosliny-warzywne). In order to facilitate protection in follow-on crops, weed species should also be identified during the cultivation of celery and their names should be recorded in the notebook.

3.1.1. Prevention and control of weeds by non-chemical methods

In the integrated protection of peppers, which is an integral part of integrated production, preventive and maintenance treatments should be used to reduce weed growth. The following requirements should be mentioned:

- Pepper should be grown in the lowest weed-infested areas. This applies particularly to peppers from early planting dates, covered with crop cover, as well as those grown in low and high foil tunnels.
- Peppers in the field and in tunnels, especially without heating, are planted relatively late, so in spring, the period from soil thawing to planting seedlings should be used to destroy weeds with mechanical treatments, carried out as necessary. However, these treatments, if repeated too often, can lead to excessive spraying and drying of the soil, especially during periods of drought. Instead of multiple crops, it is possible to prepare the field for planting with one mechanical crop – a cultivating unit. Before planting seedlings, it is also possible to partially destroy weeds in the field prepared for planting, by spraying with one of the selective agents with systemic action.
- For a few weeks before sowing or planting, the soil surface can be covered with a translucent non-woven fabric or foil for a few days to accelerate weed emergence. Then, the covers must be removed and weeds destroyed mechanically. The treatment can be used repeatedly. The method reduces the stock of vital weed seeds in the soil, and thus the level of weed infestation during the growing season. Due to the costs, this method can be applied on smaller surfaces.
- A good way to reduce weeds is to prepare the soil for planting seedlings and to irrigate the field or tunnel, and after 5-7 days, to perform a shallow cultivation, e.g., with a harrow that will destroy emerging weeds and young seedlings if they appear.
- Weeding can be reduced by mulching the soil surface before planting seedlings with light-impermeable materials, e.g., black foil or black non-woven fabric, preferably biodegradable. Mulch does not completely protect against weeds, as it does not cover the entire surface of the field; therefore, weeds grow between the covered strips of soil and need to be controlled mechanically or manually. Various deeply rooted weeds also grow in the cuttings of the foil or non-woven material, apart from the planted seedlings. They overgrow the planted seedlings and envelop the root system of the peppers with their roots. Therefore, they should be removed by hand as early as possible, very carefully, preferably by cutting right at the base, so as not to disturb the root system of the pepper.

- Bedding free from weed seeds should be used for seedling production. A few days after planting, it is necessary to check the establishment of the plants and to fill in the gaps, as weeds will grow on the bare areas. If peppers under cover are grown in rings, weed-free substrates should be used to fill them. However, it is best to use ready-made substrates. Then, the weeding area between the rings should be weeded by hand.
- When preparing for mechanical weed eradication, the distance between the rows should be adjusted to the tractor's wheelbase width and to the inter-row cultivation equipment. Weeding and mechanical treatments should be done at a shallow depth (1–3 cm), only if necessary. Frequent stirring of the rows leads to drying of the soil and deterioration of its structure; it can also damage the root system. If the field is not weedy and the soil surface is not crusted, then there is no need to loosen the soil between the rows. For mechanical weed control, angular knives should be used, preferably in combination with inter-row string rollers, inter-row springing harrows, brush routers, shallow inter-crossing inter-row rotary cultivators or other tools with shallow working parts. Nowadays, weeders equipped with brush, finger (star), and torsion elements are increasingly used.
- Manual weeding should be started immediately after the appearance of weeds. At low weed infestation, if the number of weeds does not exceed 2–3 items per 1 m^2, the first weeding can be done about three weeks after planting. With higher infestation and in conditions conducive to a faster growth of weeds, weeding should be done earlier, even about two weeks after planting. It is best to weed soon after rain or irrigation and after the soil has dried, when it is possible to enter the field. Manual procedures should be carried out very carefully so as not to damage the roots of the pepper. Larger weeds should be removed manually in such a way as not to break the brittle shoots of peppers.
- Mechanical treatments and manual weeding should be limited to the necessary minimum, because during their performance viral diseases can be transmitted. After precursor crops that leave the site in good culture, two mechanical treatments are often enough, supplemented with 1–2 manual weeding runs. In the event of weed infestation, 3–5 weeding runs may be necessary, especially in cultivation under covers.
- In field cultivation, it is also possible to thermally control weeds with special burners that burn gas from cylinders (propane). This treatment is carried out only after weed emergence, on the entire surface of the field, immediately before planting the seedlings or only in narrow strips designated within the rows. In this case, the weeds in inter-rows should be mechanically destroyed. Burners with thermal shields can also be used to control weeds in inter-rows. This method is recommended especially on organic crops.
- In crops under cover, in the period prior to planting seedlings, weeds can be thermally destroyed by performing soil steaming to combat diseases and nematodes. To destroy weeds, a temperature of about 60°C is sufficient, maintained for 20 minutes. In the periods preceding cultivation, it is also recommended to disinfect the soil in the tunnel with agents which fight the majority of harmful organisms, including germinating weed seeds. Dosage should follow the detailed recommendations given in the labels of these agents.

Note! **In order to prevent the release of seeds by weeds** and the transfer of weed seeds or their vegetative organs from neighbouring areas to the pepper plantation, **it is compulsory to mow the uncultivated areas around the plantation (e.g. baulks, ditches, roads) which belong to the same farm at least twice a year (end of May/beginning of June and end of July/beginning of August).**

3.1.2. Selection and timing of herbicide use

In the integrated cultivation of peppers, non-chemical methods of weed control play a fundamental role, and protection against weeds should be based on them. Currently, there are no registered herbicides for controlling weeds in the cultivation of peppers; therefore, it is necessary to strictly adhere to preventive measures and use non-chemical methods. However, changes in the registration of herbicides should be monitored, as it is possible to approve new products for weeding this crop. The agents recommended in other countries should not be applied. Non-selective systemic herbicides may be used in field cultivation, after the harvest of the precursor crop, in the year precursor the cultivation of peppers to control couch grass and other weeds, both annual and perennial. Non-selective herbicides can also be used in spring, before planting seedlings, if there is a sufficiently long period before starting cultivation.

3.2. Infectious diseases

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3.2.1. Diseases of fungal and fungus-like origin

Corkiness of pepper roots (cause: *Pyrenochaeta lycopersici*)

Fungi *P. lycopersici* causes a disease of the root system with a fairly mild course on field peppers. It is a much bigger problem in the cultivation of peppers under cover, due to monoculture. With a low abundance of the pathogen in the soil, no disease symptoms are observed. There are two types of disease symptoms: browning and dying of the smallest lateral roots and corking of skeletal roots - the cortical part of the roots is brown, irregularly swollen, and in places deeply furrowed and cracked. Infestation of a small part of young roots in the early stages of plant growth (often just after planting) can lead to crop losses much greater than severe damage occurring later in the growth period. Plants with severely infested roots experience stunted growth, wilting, and produce fewer and smaller fruits. The optimal temperature for pathogen development is 15–18°C. The development of the pathogen is favoured by high soil moisture and cool weather. The pathogen overwinters with residues of infested plants in the soil in the form of microsclerotia, thanks to which it can survive in the soil for several years.

Anthracnose of roots (causal agent: *Colletotrichum coccodes*)

C. coccodes like *P. lycopersici* infects the root system of pepper. Often these two pathogens occur in a complex. Anthracnose is a common disease in pepper crops. Symptoms of the disease are visible on sections or on the entire roots, in the form of browning and/or complete destruction of the cortical part, which easily slides off the root core, revealing the creamy axial cylinder. In the outer layers of the bark, one can notice small black sclerotia of the fungus. Infected plants grow more slowly and wither. Fruits do not reach the size typical of a given variety. The development of the pathogen is facilitated by high temperatures during the day, significant temperature fluctuations between day and night, and high soil humidity. The fungus overwinters on the residues of infested plants in the soil in the form of spores, from which conidial spores are formed in the spring, causing infection.

Rhizoctonia (causal agent: *Rhizoctonia solani*)

Fungus *R. solani* is a typical polyphage infecting many vegetable species. It belongs to a complex of pathogens causing seedling blight. Pepper plants can be infected at any stage of their development. Young plants are most susceptible to infection. The occurrence of the disease in the early stages of plant development can lead to their complete and rapid wilting. Symptoms of rhizoctonia are visible at the stem base, at the surface of the soil or just below it in the form of a dark brown necrotic ring. Symptoms of blight are usually accompanied by wet rot of the roots. The disease poses the greatest threat in conditions of excessive soil moisture and cool weather. The pathogen overwinters in the soil on the residues of infested plants in the form of microsclerotia, which is why the soil infection persists for many years.

Verticillium wilt (caused by: *Verticillium dahliae*)

V. dahliae is a polyphagous pathogen infecting a wide range of host plants. Verticillium wilt is a vascular disease, the harmfulness of which in the cultivation of peppers is greatest under cover. The incubation period of the disease is quite long. Symptoms usually occur shortly before the start of harvest or only during the period of full fruiting. The initial symptom is the loss of turgor by plants. Infected plants are inhibited in growth, the leaves starting from the bottom turn yellow, wither, and fall. Quite characteristic is the wilting of plants only on one side. Yellow, brownish necrosis can be observed on the edges of the leaves or between the veins. Fruits on infested plants do not reach the typical sizes for the variety. A characteristic symptom of vascular diseases is the browning of conductive bundles on the cross-section of the stem and petioles of peppers. *V. dahliae* overwinters in the form of microsclerotia, which can persist in the soil for many years. Soil contamination can reach up to 1 m. The occurrence of verticillium wilt is facilitated by light soils, insufficient calcium nutrition, and excessive nitrogen content. The severity of the disease depends on the weather conditions (the optimal temperature for pathogen development is 16-24°C) and the amount of inoculum in the soil.

Fusarium wilt (caused by fungi of the genus *Fusarium: F. oxysporum* and *F. solani*)

Fungi of the genus *Fusarium* are microorganisms commonly inhabiting the soil and even inert substrates. They belong to the complex of fungi that cause seedling blight. They infect plants at all stages of their development. Depending on the species of the pathogen, fusarium wilt can manifest as a vascular or blight disease. In the case of vascular fusariosis, plants are inhibited in growth, wither and gradually turn yellow. In general, there is no external necrosis on the roots and root collar. In the cross-section of the shoot, browned conductive bundles are visible, which prevents the plant from transporting water and nutrients. A characteristic symptom of plant infestation by *F. oxysporum f.* sp. *radicis-lycopersici* (Forl) is dry, dark brown, necrotic pitting around the root neck, visible just above the soil surface. The incubation period of vascular fusariosis is quite long. Plants usually begin to die after the start of the harvest. *F. solani* is the cause of root rot and stem base rot of pepper. A symptom observed on the aerial parts of plants is the inhibition of growth, wilting, and yellowing of the plants. The source of *Fusarium* spp. may be infested seeds. Pathogens overwinter in the form of chlamydospores and mycelium in the soil on plant residues. The optimal temperature for the development of *F. solani* is about 20°C, while for vascular fusariosis it is above 25°C.

Phytophthora disease (caused by fungi of the genus *Phytophthora*)

The culprits of the disease can be different species of the genus *Phytophthora*, but most often *P. capsici* is mentioned. These are polyphagous organisms infecting many species of cultivated plants, at all stages of their development. They are the cause of seedling blight. They cause rotting of the roots and stem base rot of pepper, as well as fruits and necrosis on the leaves. Initially, at the base of the shoot, just above the soil surface, dark green, watery spots are formed, which brown and dry over time. The rot expands from the soil surface to the upper parts of the shoot and gradually covers the entire perimeter. After removing plants from the substrate, a strongly infested and reduced root system is observed. On the leaves, the symptoms of the disease are visible in the form of dry, rapidly expanding necroses. Necrotic, rapidly enlarging rot spots may appear on the fruits, which, in favourable conditions of high humidity, are covered with a delicate white spore layer of the pathogen. Pathogens overwinter in the soil as resting spores – chlamydospores and oospores – and as hyphae on infested plant residues. Excessive soil moisture, heavy rainfall or watering of plants promote the development of phytophthora. *Phytophthora* species develop over a wide temperature range, with an optimum of 25–27°C.

<u>Prevention and control</u>

It is practically impossible to control soil pathogens during the growing season using registered plant protection products. Therefore, it is much easier to prevent soil diseases than to combat the pathogens that cause them. It will be important to maintain proper hygiene in the facilities – decontamination of tunnels and greenhouses after the end of the production cycle, disinfection of tools, use of new or disinfected multipots and **pathogen-free peat substrate for seedling production**, as well as correct crop rotation, the cultivation of plants for green fertilisers, **production of seedlings from healthy certified or standard seeds.** In the integrated production of peppers in the field and under cover, **plant health inspections should be conducted at least once a week for the presence of diseases causing wilting (e.g. fusarium wilt, verticillium wilt, phytophthorosis).** Plants showing signs of disease should be removed and the crop weeded regularly. The most effective way to eliminate soil pathogens is to disinfect the substrate with steam or a fumigant.

Sclerotinia rot (caused by: *Sclerotinia sclerotiorum*)

The fungus is commonly found in the cultivation of many species of vegetables. It affects the shoots and fruits of peppers. Infected plant tissues develop watery, necrotic spots in the form of wet rot. In favourable conditions of high humidity, the surface of the spots is covered with a white, very abundant, wadded mycelium, in which black sclerotia are formed. Sclerotia are also formed inside the shoots of plants. Infested plants quickly wither and die. The pathogen overwinters in the form of hyphae on living and dead plant tissues and as sclerotia, which can survive in the soil for several years under favourable conditions. Sclerotia are the source of primary infections. From sclerotia, in spring and summer, hyphae develop or fungal fruiting bodies grow on stalks - apothecia, filled with spore sacs. The apothecia grow from sclerotia located in the soil at a depth of no more than 8 cm. Infections are caused by ascospores and fungal hyphae. The optimal temperature for the development of the pathogen is from 15 to 20°C. Infection is favoured by high air humidity (above 90 %) and significant temperature fluctuations.

<u>Prevention and control</u>

After the end of the crop, in the autumn, it is necessary to carry out deep ploughing in order to limit the primary infections. Do not perform spring ploughing, as this will move the sclerotia of the fungus to the upper layers of the soil, potentially increasing the severity of the disease. With a large number of pathogens, chemical decontamination of the soil is advisable. A biological preparation is also available to control sclerotinia rot. **For the production of seedlings, it is required to use certified or standard seeds. Seedlings should be produced in pathogen-free substrates.** In the integrated production of peppers in the field and under cover, **plant health inspections should be carried out at least once a week for the presence of sclerotinia rot.** During the growing season, plants should be sprayed with registered fungicides, approved for IP, with different mechanisms of action. **Treatments are carried out preventively on the basis of an analysis of weather conditions or as an intervention – after the first symptoms of the disease are detected.** Agrotechnical measures to limit the severity of the disease include: frequent inspections of plant health and elimination of those with disease symptoms, regular removal of weeds, and thorough removal of debris after the completed production cycle.

Grey mould (caused by: *Botrytis cinerea*)

The most common disease occurring in the cultivation of peppers. It is a significant problem in unheated foil tunnels. The pathogen mainly attacks damaged or dead parts of plants in all developmental phases. Symptoms of the disease, in the form of watery grey-brown, rapidly enlarging spots, are observed on all organs of plants (leaves, stems, flowers, and fruits). The lower leaves that come into contact with the ground often become infected, becoming a secondary source of infection. In conditions of high humidity optimal for the development of the pathogen, grey-beige, abundant, dusty mycelium and conidial spores are observed on the infested tissues. With a decrease in humidity, the stains dry up. Wet rot is observed on the fruits. The pathogen overwinters in the soil on plant residues in the form of mycelium and sclerotia (resting forms). Infested seeds can also be a source of infection. The development of the disease is facilitated by high air humidity (above 95 %), rainfall, cool nights, dew, weakening by other pathogens, and a deficiency of potassium and calcium in the soil. The pathogen of the disease develops in a temperature range of 5-30°C, with an optimum of about 15-18°C. The harmfulness of the disease is highest during flowering and fruiting in cool and humid weather. Then the fruits of peppers rot en masse, die, and fall.

<u>Prevention and control</u>

For the production of seedlings, it is required to use certified or standard seeds. Seedlings should be produced in pathogen-free substrates. In the integrated production of peppers in the field and under cover, **plant health inspections should be carried out at least once a week, for the presence of grey mould.** The preventive use of plant protection products with different mechanisms of action is important in reducing grey mould. **Registered non-chemical agents should be included in the protection programme – at least one treatment per season should be performed with such a preparation.** In order to lower the humidity in the facility, it is necessary to ventilate tunnels and greenhouses and heat them during cold nights, which creates unfavourable conditions for the development of the pathogen. **Infested plant organs (especially fruit) and plant debris should be removed.** Regular removal of weeds reduces the severity of grey mould by increasing the airiness between plants. The cultivation of peppers in the field should be carried out in open, airy areas, far from water bodies. Plantations should not be established in hollows, with a tendency to water retention, which will promote the development of the disease.

Velvety spot of pepper leaves (caused by: *Passarola capsicicola*)

The disease occurs in the cultivation of tunnel peppers, where favourable conditions for the development of the pathogen prevail, i.e. high temperature and air humidity. Symptoms are visible on the upper side of the leaf blade in the form of light yellow discolourations and on the underside as initially small, gradually enlarging brown, velvety spots, which result from the sporulation of the pathogen. Over time, the stains merge with each other. On the upper side of the leaves, initially light yellow discolourations darken to form brown necroses. Infested leaves curl, dry up and fall. Fruits are not damaged.

Prevention and control

Maintaining unfavourable conditions for the development of the pathogen – ventilation of foil tunnels. **Plant residues should be removed after harvesting and composted away from cultivation facilities**. For plant spraying procedures, equipment with an air blower should not be used, thereby limiting the spread of spores. When the first signs of disease are found, plants should be sprayed with fungicides approved for IP.

Alternariosis of peppers (causal agent: *Alternaria* spp.)

Pathogens belonging to the genus *Alternaria* infect the leaves and fruits of peppers. On the leaves, round spots appear, initially small and enlarging over time, with a pronounced concentric zoning. The leaves turn yellow and dry. Black rot is observed on the fruits. Extensive, recessed spots with distinct edges form on the surface of the fruit. Under favourable conditions, a velvety, dark mycelial coating with conidial spores may occur on the infested tissue. During the growing season, the pathogen spreads through conidial spores via air currents and water droplets; it can also be transmitted by infected seeds. The optimal temperature for the development of the pathogen is 25°C. The pathogen overwinters in plant residues.

Prevention and control

For the production of seedlings, it is required to use certified or standard seeds. Seedlings should be produced in pathogen-free substrates. In the integrated production of peppers in the field and under cover **plant health inspections should be conducted at least once a week for the presence of alternariosis.** Preventively or after the first signs of disease, the plant should be sprayed with fungicides approved for IP. **Registered non-chemical agents should be included in the protection programme – at least one treatment per season should be performed with such a preparation.**

Avoid planting too densely and carry out regular weeding to ensure good aeration. **Infested plant organs (especially fruit) and plant residues should be removed.**

3.2.2. Diseases of bacterial origin

Bacterial blight of pepper (caused by: *Pseudomonas syringae* pv. *tomato*)

Symptoms of the disease are visible on all aboveground parts of the plant. On the surface of buds or ripe fruits, small, dark-brown spots appear, often slightly raised with sharp margins. Numerous small necrotic spots, about 2 mm in diameter, with a yellow border form on the leaves. The bacterium lives on plant residues in the soil. Seeds are also affected, which can be a source of primary infection. The bacterium spreads with droplets of water or mechanically during maintenance work. Leaf infection occurs through stomata or damaged epidermis. The incubation period of the disease is short, lasting 5 to 6 days. Bacteriosis can be observed already in the seedling phase of peppers. The disease develops strongly at 20°C.

Prevention and control

An important preventive treatment is the decontamination of the growing substrate, using a registered disinfectant or steam. Disinfection of premises and equipment used for the production of seedlings may be carried out using benzoic acid, hydrogen peroxide or sodium hypochlorite. A four-year break should be applied in the cultivation of solanaceous plants. **For the production of seedlings, it is required to use certified or standard seeds. Seedlings should be produced in pathogen-free substrates.** During care work, contact with wet plants should be avoided.

Wet rot (caused by: *Pectobacterium carotovorum* subsp. *carotovorum*)

The causative agent of the disease is the bacterium *Pectobacterium carotovorum* subsp. *carotovorum*, which causes infections in pepper fruits. Typical symptoms of the disease are maceration and rotting of parenchyma tissue, with the fruit peel unchanged. After some time, a mucous substance forms inside the fruit with a characteristic cloudy, odourless liquid that can flow out after the peel is damaged. Often, the result of infection is dried fruits on the plant, of which only the peel remains. Infection occurs at high humidity, often already during flowering.

Prevention and control

Prevention of this disease involves avoiding excessive plant density. Systematic ventilation of cultivation rooms reduces the disease. If the presence of bacteria of the genus *Pectobacterium* on cultivated plants was noted in previous years, the location of pepper production on these substrates should be abandoned. Disinfection of the substrate is also beneficial. **For the production of seedlings, it is required to use certified or standard seeds. Seedlings should be produced in pathogen-free substrates.**

3.2.3. Diseases of viral origin

Tomato spotted wilt virus on pepper (TSWV)

The most dangerous virus in the cultivation of peppers. Tomato spotted wilt virus (TSWV) affects several hundred species of cultivated and wild plants. It is transmitted by thrips, where the most important vector is the Western flower thrips. Common weeds are an important reservoir of the virus, e.g. redroot pigweed, common chickweed, groundsel and others. The most characteristic symptom is ring-shaped depressions and streaks on the fruit, often secondarily infested by bacteria. Symptoms on the leaves are less frequently observed: chlorotic and necrotic spots and streaks along the main veins on the leaves, mosaic, deformation of the leaves and plant tops, necrosis of shoots. The virus causes huge crop losses, up to 80 %, as infested fruits completely lose their commercial value.

Prevention and control

Systematic control of thrips, destruction of weeds inside and around cultivation sites, and avoidance of pepper cultivation in the vicinity of tomato, cucumber, and ornamental plants form the basis of the strategy to combat this virus. Plants suspected of being infected should be removed immediately from the place of cultivation. TSWV resistant or tolerant pepper varieties are available.

Tobacco mosaic virus (*Tobacco mosaic virus*, TMV)

TMV belongs to the genus *Tobamovirus*. The virus can be transmitted from one plant to another through direct contact. Although TMV has no identified insect vectors, it can be easily transferred from infected plants to healthy ones by humans. Another way to transmit TMV is through infested seeds. Particles of this virus are very stable and can remain capable of infection in infested crop residues, on pots, tables or wooden stakes. Symptoms of the disease are more intense in spring and late autumn, with short days and insufficient light. A typical symptom of TMV on peppers is a mosaic on the leaves, with inhibition of the growth of the infected plant and limitation of fruit formation. TMV can cause necrotic streaks on the stems and fruits of peppers. Tissue necrosis inside the fruit is also observed. On infested peppers, the dropping of buds and curling of leaves towards the lower side are recorded. There may be yellowing of the leaves.

Prevention and control

The basis for preventing the occurrence of the disease is the cultivation of resistant varieties. **For the production of seedlings, it is required to use certified or standard seeds. Seedlings should be produced in pathogen-free substrates.** An important preventive treatment is decontamination of the growing substrate, using a registered agent or steaming of the substrate.

Cucumber mosaic virus (*Cucumber mosaic virus*, CMV)

The presence of CMV is noted especially in late summer, when it causes significant losses. It can be transmitted by aphids during the growing season, as well as during maintenance work. Typical symptoms of CMV on peppers are the mosaic seen most often on the youngest leaves and irregular, necrotic spots with a dark border on the surface of the leaf blades. The leaves are inhibited in growth. Typical symptoms on fruits are yellow-green, brown spots in the form of mosaics and corking. The fruits are deformed and do not grow to the typical size for a given variety.

Prevention and control

Varieties resistant or tolerant to the virus should be selected for cultivation. **For the production of seedlings, it is required to use certified or standard seeds. Seedlings should be produced in pathogen-free substrates.** Due to the transmission of the causative agent of the disease by aphids, protection of peppers against pests should be carried out, and seeds should be obtained from a reliable source. Weeds must be combated. Registered disinfectant or steam may be used to disinfect the substrate.

3.3. Pests

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Knowledge of the biology of pests, their periods of occurrence, and harmfulness forms the basis for adopting effective protection methods. The following are pests commonly found on peppers in field conditions, unheated plastic tunnels and in a greenhouse.
Chemical plant protection products registered in Poland include:

- - select chemical agents intended to control a specific group of pests;
- limit the use of preparations from the group of synthetic pyrethroids due to their high toxicity to beneficial insects.
- select agents with the shortest withdrawal and prevention period.

The most important pests in the cultivation of peppers under cover include parasitic nematodes, mainly the northern root-knot nematode; among the mites are the broad mite and the hot spider mite; and among the insects are aphids (cotton aphid, peach aphid, striped potato aphid, potato aphid), thrips (tobacco thrips, western flower thrips), European tarnished plant bug, leaf miners (tomato leaf miner), gamma moth, and bright-line brown-eye.

NEMATODES (Nematoda) - family Meloidogynidae

Northern root-knot nematode (*Meloidogyne hapla* (Chitwood))

This nematode poses a threat in different types of soils and organic substrates. In mineral substrates, root-knot nematodes can only be a problem once previously infested material has been planted out. On the roots of plants colonised by the nematode, nodes, or so-called ‘outgrowths’ of several millimetres develop. Root damage and distortion occur due to limited water and nutrient conduction in plant tissues. Plants affected by root-knot nematodes are more sensitive to sunlight and drought. There are usually two generations of nematode, however, in greenhouse cultivation, due to temperature conditions, their number may be higher. The optimal moisture content for the development of this pest is between 40-80%. The second stage larvae (J2) hatch at a temperature of approximately 12°C, while root penetration and further development take place at a temperature of 18-21°C. The development time of one generation of the nematode depends largely on the temperature. In the climatic conditions of Poland, the development of the first generation of the nematode lasts from 9 to 13 weeks.

Prevention and control

Before starting cultivation, it is recommended to perform a soil test for the presence of invasive larvae of the northern root-knot nematode. This analysis should be performed at the turn of April and May, when J2 invasive larvae hatch from eggs. Later, the abundance of larvae in the soil decreases, as they penetrate into the roots of plants. The re-emergence of J2 larvae in soil is observed at the turn of August and September.

In the growing season, it is recommended to perform root analysis, which allows for the detection of the nematode in the crop even at times when juveniles are not observed in the soil. In order to obtain root samples, it is necessary to dig up the entire root ball of the plant, paying attention to collect very fine roots. The level of tolerance to the settlement of pepper roots by the northern root-knot nematode is not known, but due to the significant contribution of this nematode to complex plant diseases, it is necessary to limit its occurrence in the cultivation of peppers under cover.

In the cultivation of peppers, mainly recommended are treatments that increase the resistance of roots to damage caused by nematodes, e.g. the use of mycorrhizal fungi, PGPR (plant growth promoting) systems using bacteria, silicon compounds and other substances that increase the resistance of plants to biotic and abiotic stress, as well as selected actinomycetes (production of substances toxic to nematodes) and entomopathogenic fungi (reduction of the number of eggs and nematodes). **In cultivation under cover** nematodes are radically eliminated by thermal or chemical decontamination of the substrate. **In field cultivation**, where nematodes are found on the roots of peppers, crop rotation should be introduced, including cereals, maize, cucumber, and varieties of other species resistant to nematodes.

MITES (Acari) – family Tarsonemidae

Broad mite (*Polyphagotarsonemus latus* (Banks))

It is commonly found on many species of ornamental plants and on some vegetables, including peppers grown in greenhouses and polytunnels. It is most often introduced with pepper seedlings. Adults and larvae feed on the underside of the leaves, causing them to russet and curl the edges of the leaves upwards. Strongly damaged plants are inhibited in growth. The female body is broadly oval, convex, and 0.2-0.3 mm long. Young females are whitish, while mature ones are straw yellow with a faint white streak along the back. They have three pairs of legs of similar construction; the fourth pair is filamentous. Males are half the size. As in the female, three pairs of legs are similar in structure, with the fourth pair in the form of claws, which are used to carry larvae. Larvae are similar in appearance to adults; they have only three pairs of legs, initially whitish, later transparent.

Eggs are oval with a flat base, featuring numerous round protrusions arranged in longitudinal rows, transparent and iridescent.

In optimal conditions, at a temperature of 25°C and high humidity, the development of one generation (from egg to adult form) lasts approximately 4 days, and at 15°C it is extended to approximately 15 days. A female, during a lifespan of approximately 15 days, lays 25-75 eggs, 2-5 per day, on the underside of leaves along the veins, on flowers, or in cavities on the shoot. The development of the mite is inhibited when the air humidity is below 30 % or above 90 %, and the temperature is below 12-14°C or above 33-35°C.

Prevention and control

Mites can be detected using a magnifier with 10x magnification by examining the underside of the leaves on 50 randomly selected plants in 5-10 different cultivation sites. The hazard threshold is the detection of mites on more than 5 plants. After detecting mites, it is necessary to proceed with control measures using chemicals registered for the IP of peppers under cover.

MITES (Acari) – family Tetranychidae

Hop spider mite (*Tetranychus urticae* Koch = *Tetranychus cinnabarinus* (Boisduval))

This mite is found on more than 300 species of cultivated and wild plants. Among cultivated plants, it is often found on ornamental plants and vegetables grown under cover, including peppers. Adults and larvae of the hop spider mite feed on the leaves, sucking out the contents of the cells. Symptoms of feeding are visible in the form of small, bright spots that gradually cover the entire surface of the leaf. Strongly attacked leaves turn yellow and fall. In conditions of low humidity, the plants inhabited by mites are covered with a delicate spider web. Summer females are up to 0.5 mm long, transparent, with two darker spots on the sides and 4 pairs of legs. Males are smaller than females, 0.3-0.4 mm long, oval-shaped with a sharply pointed back, and a lighter body colour. The larvae are similar to adults, but smaller and have only 3 pairs of legs. Eggs are shiny, bright yellow. Winter females - brick-red.

Fertilised females overwinter individually or in groups, hidden in mats, structural elements of greenhouses or tunnels, on plant residues left behind or under clumps of substrate. In crops under cover, in March or April, when the air temperature rises above 12°C and the day is longer than 14 hours, females begin laying eggs. One female, during a lifespan of 3-5 weeks, lays up to 100 eggs. Development of one generation (from egg to adult) takes an average of 1-2 weeks. The optimal conditions for the development of the hop spider mite are a temperature of approximately 25°C and a relative air humidity of up to 70 %.

Prevention and control

The hop spider mite is a dangerous pest of peppers, and if detected late, it becomes difficult to control. Therefore, early detection is extremely important for effective protection. **After planting seedlings both in the greenhouse and in the field, the plants should be systematically inspected, at least once a week, paying attention to the appearance of the lower side of the leaves.** In crops under cover, plants growing near heating pipes, which are the first to be inhabited by mites, should be particularly controlled.

In crops under cover, the threshold of danger is the detection of several plants with symptoms of leaf foraging. Hop spider mite occurs mostly in patches, feeding for a long time only on a dozen neighbouring plants. Therefore, eradication measures can initially be limited to infested plants. For the control of spider mites, chemical agents registered for the IP of peppers under cover can be used. When opting for biological control in greenhouse pepper crops, it should be initiated after the first signs of damage or the first outbreaks of spider mites on plants, in the area affected by the pest.

THRIPS (Thysanoptera) – family Thripidae

In the cultivation of peppers under cover, both tobacco thrips and western flower thrips may occur, while in field crops only tobacco thrips are found.

The individuals and larvae of thrips feed on the underside of leaves, flower buds, flowers, and forming fruits, as well as on the stalks and the stalk area of the fruits. Damage to the underside of the leaves is visible in the form of silvery streaks with black clumps of faeces, while on the upper side of the leaves in these places yellow spots form, which brown over time. Insects feeding on the stalks and the stalk area of the pepper fruit hide under the sepals. At the site of injury, the skin cracks and becomes corky. With a high intensity of the pest, flower buds and young fruits drop most often. On the surface of the fruit, the symptoms of thrips feeding are visible in the form of slightly concave and watery spots. Thrips are vectors of the Tomato Spotted Wilt Virus (TSWV).

Tobacco thrips (*Thrips tabaci* (Lindeman))

Adult individuals are up to 1.2 mm long with variable body coloration; From light yellow to black, the antennae are 7-segmented. The larvae are yellow, similar to adults, but do not have wings. Pupae are slightly larger and darker than the larvae, with the beginnings of wings. This pest winters in post-harvest residues of many crop and weed species, in the soil and storage rooms.

The development of the tobacco thrips from an egg to an adult takes about 1 month. Under field conditions, it can develop from 2 to 4 generations, and under cover up to 10.

Western flower thrips (*Frankliniella occidentalis* (Pergande))

The species differs from tobacco thrips in the presence of 8-segmented antennae and body colour, from yellow to brownish-yellow. The larvae are wingless, initially light cream, and later light yellow. In Poland, the pest can only survive in greenhouses and heated tunnels. The development of one generation lasts an average of 1 to 2 months.

<u>Prevention and control</u>

Immediately after planting the seedlings in a permanent location, at least once a week, the leaves of the plants should be inspected for larvae and adult thrips. Blue or yellow sticky boards are very helpful in the early detection of thrips. **Under cover** the effectiveness of detecting Western thrips is increased by the use of attractant. In the greenhouse, 1 board must be displayed per 100 m² of crop. They should be reviewed at least once a week, and when they are completely covered with insects, they need to be replaced. The presence of 2-4 thrips caught during the day means a treatment should be proceeded with. In addition, it is recommended to inspect plants at least once a week for the presence of larvae and adults.

In the absence of effective control of thrips or at the time of a sharp increase in their number, it is necessary to carry out a minimum of 2 treatments with agents currently registered for the control of thrips on peppers at 7-day intervals. For the treatment, depending on the development phase of the plants (size) and planting density, 300 to 2000 litres of usable liquid per hectare should be used.

In crops under cover, when deciding to biologically control thrips immediately before the introduction of parasites, predatory mites, or true bugs, the boards should be removed from the greenhouse.

The number of thrips **under field conditions** during the growing season significantly reduces the collection and destruction of crop residues, as well as weeds in the crop and its surroundings. Where possible, the proximity of crops to host vegetables, such as onions, should be avoided. After harvesting the crop, it is a good idea to carry out deep ploughing. The occurrence of thrips should be monitored from May to July, inspecting the lower side of the leaves for the presence of individuals and foraging sites. **Blue or yellow sticky boards can also be used for this purpose and should be placed on the plantation at a rate of 4 units/ha.** As in the cultivation of peppers under cover, the plants should be inspected at least once a week for the presence of larvae and adults. Eradication should be carried out after individual specimens have been found on plants. It is required to apply the chemicals recommended for integrated production from the clearly developed first leaf stage until full flowering, no more than 3 times per season and no more often than every 7-10 days.

TRUE BUGS (Hemiptera) – family Aphididae

Peppers are inhabited by several species of aphids. In addition to the most common **peach aphid** (*Myzus* (*Nectarosiphon) persicae* (Sulzer)), in particular on peppers grown under cover, other species may occur, namely: cotton aphid (*Aphis gossypii* Glover, 1877), striped potato aphid (*Macrosiphum euphorbiae* (Thomas, 1878)), medium potato aphid (*Aulacorthum solani* Kaltenbach, 1843).

Aphids feed on the entire surface of the plant: on leaves, stems, flowers, and fruits. The leaves infested by aphids turn yellow, and the whole plant is inhibited in growth, producing a delayed and much lower yield. Both adults and larvae suck the sap from leaves, flower buds, flowers, and fruit primordia. With a high density of aphids, the leaves of the plants turn grey, and the flowers and fruit buds fall. In addition, on the leaves and fruits covered with honeydew, excreted during the feeding of aphids, sooty moulds develop, limiting the assimilation surface of plants, and this leads to a decrease and deterioration of the fruit yield. **All aphid species listed are vectors of viruses.**

Peach aphid – (*Myzus* (*Nectarosiphon) persicae* (Sulzer))

Wingless aphids are about 2 mm long, green, yellow or olive in colour, while winged individuals are up to 2.3 mm long. The head and thorax are black, and the abdomen is olive-green with a large dark spot in the middle. The antennae reach to the base of the siphons. The larvae are similar to wingless individuals, but slightly smaller.

It is a two-host species. In the greenhouse there are anholocyclic forms (without sexual reproduction). In field conditions, the peach aphid overwinters in the egg stage on trees of the genus *Prunus*, mainly on peach, Chinese wolfberry, or on various crops in greenhouses, and in storage facilities for vegetables, potatoes, and ornamental plants. Winged aphids migrate to peppers in May and June. It takes 12 - 14 days for one generation to develop.

Cotton aphid (*Aphis gossypii* (Glover))

It is found all over the country; besides peppers, it also feeds on cucumbers. It is a two-host species, overwinters as eggs on the primary host e.g. alder buckthorn, common buckthorn, and develops on the secondary host – herbaceous plants e.g. cucumber – during summer, and returns to the primary host at the end of summer. Winged females are up to 1.9 mm long. The head and thorax are black, and the abdomen is green with dark spots on the sides. Wingless females 1-1.5 mm long are variable in colour, ranging from light yellow to dark green with dark siphons. Legs are bright with dark tops of shins and feet. Larvae - colours from grey to green. Several generations develop during a year. Eggs overwinter on the shoots of bushes, including alder buckthorn and common buckthorn, or develop throughout the year in greenhouses. In spring, larvae hatch from the winter eggs and initiate development of 2-3 generations. In summer, winged forms form and fly to summer hosts, including cucumbers, where several generations of wingless forms develop. Under optimal conditions, with an air temperature of 21-27°C, females give birth to larvae within 15 days. In autumn, winged forms emerge and return to the primary host where females lay winter eggs.

Striped potato aphid (*Macrosiphum euphorbiae* (Thomas))

The females are green and grow to 3.8 mm in length. Their antennae and syphons are long. It takes between 8 and 17 days for one generation to develop, depending on conditions. Under optimal conditions, this aphid forms large populations and can develop up to 4 generations in a month.

Medium potato aphid (*Aulacorthum solani (*Kaltenbach))

A species with relatively large body dimensions. Females grow up to 3 mm in length, have a green or yellowish body and syphons (up to 1/4 of the body length) traps. At the base of each syphon, there is a green stain. This species occurs in the greenhouse. Its biology is similar to that of the striped potato aphid.

<u>Prevention and control</u>

Yellow sticky boards can be used to monitor the presence of aphids in crops under cover, which should be hung above the plants at a rate of 1 per 100 m². Inspection of plants for the presence of aphids should be carried out at least once a week. Both in crops under cover and in the ground, plants should be systematically inspected throughout the growing cycle, preferably at weekly intervals. Before planting the seedlings in the field, they should be checked for infestation with aphids. Aphids should be controlled after their appearance on the plant. The chemicals recommended for integrated production, preferably selective, with short withdrawal and prevention periods should then be used. Treatments with chemical agents should be repeated as necessary, varying the preparations, because subsequent generations quickly become resistant to chemical substances.

TRUE BUGS (Hemiptera) – family Miridae

For peppers, the biggest threat is **European tarnished plant bug.** In addition to this species, there may also be **Lygus pratensis** (*Lygus pratensis* (L.)), **Apolygus lucorum (***Apolygus lucorum* (Meyer-Dür)) and **Orthops campestris (***Orthops campestris* (L.)). The mentioned species of newts look similar, but differ, among others, in size, pattern, and colouration of the body.

Adult insect and larvae pierce the tissue and suck juices from leaves, flower buds and flowers.zbo They mainly damage the apical parts of plants. Severely damaged flower buds and flowers fall. Plant bugs cause the most damage to the fruit. On the surface of green, developing fruits, dark spots are observed with a lighter halo, several millimetres in diameter, sometimes grouped in pock-like clusters. As the fruit matures, its colour becomes more intense, with the colour of the coating (light or greenish) remaining unchanged until harvest.

European tarnished plant bug (*Lygus rugulipennis* (Poppius))

The dominant species, most commonly found on peppers. Adults are green-yellow or brown in colour, with lengths ranging from 4.7 to 5.7 mm. On the dorsal side, on the pronotum, they have a yellow spot resembling a triangle. The egg is elongated, cream-coloured, with a length of up to 1 mm. The larva is slightly smaller, with four black spots on the upper side of the body. The nymph, similar to an adult, is green with the beginnings of wings.

In the plant bugs, adult insects overwinter in crop residues, wasteland, on baulks and stubble, in the mulch of field trees, deciduous forests, coppices, etc. There are two generations per year. Larvae appear on plants from the end of May and in June. Adults of this generation appear in July, and most abundantly from the second half of July. The second generation occurs from August.

<u>Prevention and control</u>

In the case of numerous plant bugs, it is advisable to install nets at the entrance to the tunnels. This protects the pepper completely because these insects fly in from the outside. When noticing the first damage on the fruit, chemical treatment involving spraying plants with one of the insecticides for this purpose should be performed.

FLIES (Diptera)
Fungus gnats (*Bradysia* spp.) **- family Sciaridae**
Shore fly (*Scatella stagnalis*) - **family Ephydridae**

They pose the greatest threat to seedling production. They live in the decaying organic debris of the substrate. Larvae are also eager to feed on dead roots and dead plant tissue at the root collar. Larvae of the shore fly can also initially damage both the underground parts and the base of the shoot, so they can also appear on seedlings produced in mineral wool and coconut. The presence of flies is facilitated by a moist substrate and the algae, lichens, and mosses growing on it. Plants infested by fungus gnats grow poorly, turn yellow, and rot at the base near the root collar.

Adult flies are about 3 mm long, have a black head and thorax, and a greenish-brown abdomen and long black legs. Shore flies have bright spots on their wings and red eyes. Eggs are oval, yellow-white, up to 2 mm long. The larvae are worm-like, with a transparent body and a clearly visible gastrointestinal tract, growing up to 5.5 mm. The whitish pupa changes colour to dark before pupation. The development from egg to adult takes about 3 weeks. Adult flies live for about 7 days.

Prevention and control

After planting, one or two yellow boards should be placed for every 100 m^2 of crops to inspect for the presence of flies. The boards should be inspected weekly. Once flies are found, control treatments should be proceeded with. Due to the lack of registered means for controlling fungus gnats, it is recommended to conduct control using a biological method by introducing predatory nematodes into the substrate, at the root collar of the plant. Keeping the surface of the growing medium low in moisture (e.g. sprinkling the surface of the peat substrate with a 0.3- to 0.5-cm layer of fine, baked sand) is conducive to reducing the feeding of the larvae.

FLIES (Diptera) - Leaf miners (Agromyzidae)

Among the leaf miners found in the cultivation of peppers, the following is commonly found: **potato leaf miner** (*Liriomyza bryoniae* (Kaltenbach)). The following are also frequently identified: **pea leaf miner** (*Chromatomyia horticola* (Goureau) **=** *Ch. atricornis*)) and **leafminer fly**(*Liriomyza strigata* (Meigen)).

The body length of adult leaf miners does not exceed 2.3 mm. The larvae are legless, pale yellow or whitish, up to 3.2 mm long. The eggs are whitish, elongated, up to 0.3 mm long. The pupae are initially light, later turning brown, with a length of up to 2.3 mm.

Potato leaf miner (*Liriomyza bryoniae* (Kaltenbach))

The development cycle occurs on plants grown under cover, producing up to four generations, while the remaining species of leaf miners develop two, sometimes three, generations during the year. Pupae overwinter in the ground.

Leaf miners are often introduced into greenhouses with plant material. The first signs of the presence of leaf miners on plants are visible on the surface of the leaves in the form of punctures with a lighter halo. The larvae feed in the cotyledons and inside the leaves, creating winding corridors called mines. Several larvae can feed simultaneously on one leaf. Severely damaged leaves die. They pose a threat mainly during seedling production.

<u>Prevention and control</u>

The incursion of flies into the tunnel is recommended to be signalled by means of yellow sticky boards placed at a density of 1 per 100 m^2 in its peak sections, after planting the plants. After capturing flies on boards or larvae on leaves, it is necessary to proceed to the eradication of leaf miners. In addition, it is necessary to conduct systematic inspections of plants, during which attention must be paid to the appearance of the leaves. The signal to perform protective treatments with chemical agents is the detection of 8-10 leaves with punctures or mines on an area of 10 m^2. The control of the aforementioned species of leaf miners can also be carried out by a biological method involving the introduction of parasitic wasps on the plant inhabited by the species of the pest in question.

BUTTERFLIES (Lepidoptera) – family Gelechiidae

Tomato leafminer (*Tuta absoluta*)

The tomato leafminer, in addition to peppers, occurs on tomatoes, aubergines, and potatoes. Plants are attacked at every stage of growth. Juvenile caterpillars feed inside the leaves by eating the ground tissue in the shape of square mines. They can also damage stems and green fruit by biting into them. The presence of the pest is evidenced by the excrement of caterpillars on apical buds, flowers, and fruits. The yield and quality of the crop are destroyed.

Females of this butterfly are greyish brown with darker mottling, about 6 mm long, and have a wingspan of 10 mm. Caterpillars of younger stages are 0.5 mm long, yellowish in colour. In the last stage of development, they reach about 9 mm, are yellow-green, slightly pinkish on the dorsal side, with a dark neck disc.

The development of one generation, depending on the temperature, takes 29-38 days. Butterflies are active at night, hiding between the leaves during the day. Females lay eggs on tomato leaves, averaging 260 each. There are four larval stages. Caterpillars pupate on leaves, inside mines or in the substrate.

<u>Prevention and control</u>

Delta traps with pheromones are used to detect butterflies, observe their flight and abundance. The danger threshold is to catch more than 30 butterflies/trap in a week or damage to more than 5% of the fruit. Once the risk threshold is exceeded, a decision to start control activities must be taken. Bacterial agents containing in their composition *Bacillus thuringensis* ssp. *kurstaki* or *Aizawai* should also be used to control butterfly caterpillars.

BUTTERFLIES (Lepidoptera) – family Noctuidae

The species most often found on peppers in the greenhouse include Mamestra *(Mamestra spp.)* and **gamma moth**(*Plusia gamma* (L.)), as well as **the bright-line brown-eye** (*Helicoverpa armigera* (Hübner)).

The caterpillars of these butterfly species initially feed in clusters, then diverge, biting out various shapes and sizes of holes in the leaves. There are dark faeces in the vicinity of the damage. Very young caterpillars sometimes bite inside the pericarp, there they grow, biting and polluting the fruit. Such a fruit ripens faster, but does not acquire a characteristic colour, which indicates the presence of the pest, despite the lack of visible damage. Clear holes are created when the caterpillar gets out. These butterfly species cause damage to peppers usually in the second half of summer, but it happens that they also attack late seedlings.

Butterflies of these species are quite large. The range of grey-brown wings of piętnówka and gamma moth is 42 mm. Depending on the species, on the front pair of wings there is a characteristic drawing formed of darker spots. The eggs are barrel-shaped, whitish immediately after laying, darkening as they mature to a brownish colour. Young caterpillars are light green, but as they grow up, depending on the species, change colour to dark green, grey, brownish brown and almost black. Fully grown caterpillars are large (about 50 mm) and spiny.

Female **bright-line brown-eye** has wings ranging from light yellow to reddish-brown, and a male greenish (with a span of 30-40 mm). Caterpillars range in colour from yellow to reddish-brown and greenish with dark stripes on the back. The development lasts 2-3 weeks. The caterpillars feed mainly in the top parts of the shoots, damaging young leaves, buds and fruits and leaving yellowish clumps of excrement.

<u>Prevention and control</u>

At least once a week, the crop should be inspected for the presence of caterpillars. Once a pest has been spotted, a decision must be taken to eradicate it. For control, it is recommended to use one of the bacterial agents containing in its composition *Bacillus thuringensis* ssp. *kurstaki* or *aizawai*.

CUTWORMS (*Agrotis* spp.)

There are dozens of species of cutworms in Poland. One of the most common and harmful is **turnip moth** (*Agrotis segetum* (Denis & Schiffermüller)). The following can be present in slightly lesser intensity: **rolnica czopówka** (*Agrotis exclamationis* (L.)), **rolnica gwoździówka** (*Agrotis ipsilon* (Hufnagel)) and **rolnica panewka** (*Xestia* (*Megasema*) *c-*

nigrum). All are polyphagous and feed on a wide range of cultivated and wild plant species from a number of botanical families.

Young caterpillars feed on aboveground plant parts, damaging leaves or emergent plants. The older ones also damage the underground parts and come out at night to bite the plants at the root. One caterpillar can destroy up to several plants. In the event of heavy pest infestation, sites devoid of plants (known as 'bald spots') may occur.

Butterflies have a wingspan of 2.5-4.5 cm. Their wings range in colour from light beige to grey-brown. The front wings are darker than the rear ones and have different patterns – round, oval and kidney-shaped spots and bands. Caterpillars are from 3.0 to 6.0 cm long, cylindrical, grey, brown or olive, glossy. At rest or in case of anxiety, they curl up in a glomerulus. The pupa is closed and reddish-brown.

Caterpillars or pupae overwinter in the ground (down to about 20 cm). Caterpillars leave their winter hideouts and start feeding in April when the soil temperature exceeds 10°C. They then bury themselves in the soil to pupate. Butterflies fly out in May-June. They are active at dusk and at night. Females lay eggs (up to 2 000 eggs) in the soil or on plants. Young caterpillars hatch after 5-15 days and feed on the plant during the day. The older ones are mainly active at night and hide underground during the day. Depending on climatic conditions, they can develop 1-2 generations per year.

<u>Prevention and control</u>

The primary method of limiting the number of agrophytes is through properly managed agro-technique. Immediately after harvesting the precursor crop, shallow tillage and deep ploughing in autumn as a significant proportion of caterpillars and pupae are killed during these treatments. In areas where agrophytes have been found, wasteland creating excellent conditions for their reproduction should be ploughed up. During the growing season, flowering weeds that are a source of food for butterflies should also be destroyed in and around plantations. In order to determine the threat to the crop from the cutworms, monitoring for the flight of the butterflies (especially the turnip moth) should be carried out with pheromone traps between the beginning of May and the end of September. The traps (2 pcs./ha) are always placed over the tops of the plants and checked at least twice a week for the presence of butterflies. In addition, systematically, at least once a week, plants should be inspected for the presence of caterpillars which usually appear 15-25 days after the peak in butterfly numbers is recorded. Finding the first young caterpillars on the leaves is a signal that activities to combat this pest should begin. For the control of cutworm caterpillars, it is recommended that bacterial agents be used in the first place. Chemical control involves spraying insecticides registered to control cutworms on peppers. Due to local nature of occurrence of the pest, the first treatment can be limited to areas where caterpillar presence has been identified. Treatments should be carried out in the evening.

BUTTERFLIES (Lepidoptera) - family Pyralaidae

European corn borer *Ostrinia nubilalis* (Hubner)

Caterpillars of European corn borer mainly bite into green and red pepper fruits. They drill the corridors in the flesh of the fruit, without biting the outer skin. They especially often feed (wrapping gently with yarn) within the seed nest and inside the stalk of the fruit. Damage can be observed only when the fruit is very damaged or begins to rot. Damage to drip lines is also observed, which are bitten by caterpillars trying to get into the water (especially during periods of drought and high temperatures). The severity of the occurrence of borers is observed periodically, every few years.

Females have yellow-olive wings with a brown drawing with a span of 30 mm, while males' wings are dark brown with yellow patches. The caterpillars are initially yellow, later they become light grey-brown with a dark brown stripe along the back and small spots on the sides.

Prevention and control

It is advisable to put on nets, which completely protects the peppers, since these insects come from the outside. Pepper crops should be located away from maize crops and from post-maize sites. Pheromone traps that catch males can be helpful in alerting the presence of borers. The trap should be set outside the cover, near it, during the butterfly flight period (May, June). It should be remembered that harvesting butterflies is not synonymous with the presence of caterpillars in the crop; it only gives information about the presence of this species in the area and its abundance. The presence of caterpillars can only be determined on the basis of carefully conducted crop vetting. The control of the borer is carried out in the same way as the stigmas and gamma moths.

SNAILS AND SLUGS (Gastropoda)

Snails can pose a certain risk to pepper fruits in conditions of high humidity. They mainly damage fruits and their stalks, but they can also feed on roots in seedling containers.

Prevention and control

Snails should be collected, trapped (e.g. flat beer containers) or controlled with chemical agents registered to control these pests in pepper crops. Biological preparations containing parasitic nematodes are also available to combat snails.

3.4 Protection of beneficial organisms and creating conditions conducive to their development

MSc Eng. Mikołaj Borański

Chemical plant protection products, as well as some mechanical treatments, can have an adverse effect on beneficial organisms which play an important role in reducing the occurrence of pests. Increasing the diversity of plants in the vicinity of the field has a positive impact on beneficial organisms and promotes their development. Limiting the weed to the necessary minimum, which does not threaten to reduce crop yields, makes it possible to

increase biodiversity in the agricultural environment. The protection of beneficial organisms, including parasitic and predatory insects, spiders (cobweb spiders and harvestmen) or insect-eating birds, consists in creating a favourable habitat for their development. Clusters of nectar-giving trees and shrubs, and herbaceous plants blooming near crop fields called ‘refugias’ provide beneficial organisms with large amounts of nectar and pollen rich in protein necessary for their proper development. It is also advisable to create in such areas breeding sites for insect-eating birds. Knowledge of the biology of the pest and of its natural enemies makes it possible to determine a time of control that will be safe for the beneficial organisms. Among zoocides used for controlling pests, priority is given to biological agents and selective products, i.e. those that have effect on a specific group of harmful organisms and are safe for the beneficial organisms.
In vegetable crops, such conditions are met by biopreparations containing spore-forming bacteria (eg. *Bacillus thuringiensis*, which are recommended for combating caterpillars) and entomopathogenic nematodes - *Steinernema feltiae.*

Fields of protection

There are numerous mites, as well as predatory and parasitic insects in the cultivated fields. Among the predatory insects, the most numerous are beetles from the following families: ground beetles (Carabidae), rove beetles (Staphylinidae), ladybugs (Coccinellidae) and soldier beetles (Cantharidae); from the order Neuroptera - Chrysopa spp. and true bugs belonging to the families of mirid bugs (Miridae) and damsel bugs (Nabidae); Diptera from the following families: hoverflies (Syrphidae), tachinid flies (Tachinidae), gall midges (Cecidomyiidae), house flies (Muscidae) and robber flies (Asilidae), as well as a number of spider species belonging to the *Trombidium* genus. Common parasitic insects are Hymenoptera belonging to the following families: ichneumon wasps (Ichneumonidae), braconids (Braconidae) and Chalcididae.

Principles of conservation of useful species:

- Use plant protection products after the threshold of harmfulness has been exceeded, at times safe for beneficial organisms.
- Avoid the use of zoocides with a wide spectrum of action and a high level of harmfulness to the environment.
- Abandon chemical control when the pest population is small and there is no threat of drastic reduction in yield, and numerous beneficial organisms are present in the field.
- Control pests on the borders of the crop or in spots if the pests are not present all over the field.
- Carry out the treatments only in the necessary number to minimise mechanical damage to plants from the equipment used. This goal can be achieved by means of using mixtures of plant protection products or ready-made two-component preparations.
- Leave baulks, refuges, midfield trees and other belts of greenery where multiple beneficial organisms can live.

- Before starting a procedure, familiarise yourself with the content of the label on the plant protection product. Pay particular attention to warning pictograms and statements.
- Non-application of measures during the flowering period of plants during the flight of bees. This rule also applies to agents showing low toxicity to bees or bearing a label with a statement: bee re-entry period – not applicable. Every product, even the one that is 'safe' for bees, has a specific smell. That smell preserved on workers returning to the hive is information for the guards, which will not allow such workers to enter the hive, as they smell different from the other bees belonging to the colony.
- Not performing chemical treatments on fields where weeds bloom eagerly visited by bees. This applies not only to vegetable crops, but also to other places surrounding a given field, to which the spray liquid can drift.
- Use low-toxic agents, safe for bees and other pollinators.
- Observe strictly the re-entry period.
- Use appropriate nozzles or shields to prevent the drifting of spray liquid during the procedure.
- Carry out protective treatments during periods when bees are not active due to the time of day or weather conditions.
- Provide appropriate protection to hives in a situation where the spray liquid can penetrate inside. Bees are protected by law, and therefore producers causing the death of bees in an unintentional or purposeful manner are subject to financial punishment. Control over the correct use of plant protection products is exercised by the provincial plant protection and seed inspectorates. Poisoning of queens of wild bees and of other pollinating insects (bumblebees, solitary bees, mason bees) is particularly dangerous in spring, when the queens construct nests and are in the process of reproduction. The death of pollinators during this period prevents the development of the next generation.

The quantity and quality of a vegetable crop depends significantly on the presence of pollinating insects such as Hymenoptera, Diptera, and butterflies. For economic reasons, the most important group of Hymenoptera are bees, among which honeybee, bumblebees, and solitary bees (e.g. the red mason bee) can be distinguished. The presence of pollinators around vegetable crops, including field pepper, can be supported by leaving or creating food-abundant places for them, e.g. flower belts, as well as refuges and nesting places, such as houses for mason bees and houses or mounds for bumblebees in the number of at least 1 piece per 5 ha (in the case of larger plantations – several pieces per 5 ha). The preferred place to set up houses for mason bees and bumblebees is at the edge of the plantation so that their exits face south. The interior of the house for mason bees should consist primarily of tubes of common reed, 18-20 cm long and of variable diameter of 6-8 mm. Each tube should be prepared so that it is tightly closed on one side (by cutting it off just behind the node) and open on the other. The tubes are then clustered together in bundles of several dozen and placed horizontally in the house. The outlet holes should be protected against birds using netting with openings with a diameter of 8-10 mm.

A house for bumblebees should be a wooden box with dimensions of approx. 15×15×15 cm. The front, moving wall of the house should be provided with an outlet opening with a diameter of 2 cm. The interior of the house should be lined with dry material for the construction of the nest, for example grass, sawdust or moss. The house is placed directly on the ground or dug into the ground up to half its height to create so-called mounds.

IV. COLLECTION, STORAGE AND PREPARATION FOR MARKETING

Dr M. Grzegorzewska

4.1. Harvest and quality assessment

Peppers may be harvested at different stages of consumer ripeness, i.e. from phase I (green grown fruit) through phases II, III and IV (semi-coloured fruit) to phase V (fully coloured fruit). When growing crops under shelter, the first two harvests are often carried out ‘green’, i.e. harvesting overgrown green fruits. The earlier removal of the grown fruit allows the plant to better expand its vegetative mass. Fully coloured fruit is usually harvested during full fruiting. Depending on the variety, the fruits can be red, yellow, orange, purple, etc. Harvesting is done very gently, cutting the fruit with a sharp pruning shear next to the plant itself (leaving the stalk as long as possible). Some producers break out the fruit in the knee of the stalk (this place heals relatively quickly, making it difficult to infect with grey mould spores). During or immediately after harvesting, the fruit is selected, eliminating sick, damaged or distorted fruit. The requirements of the general marketing standard for fruit and vegetables and the specific marketing standard for sweet peppers (Commission Delegated Regulation (EU) 2019/428 of 12 July 2018 amending Implementing Regulation (EU) No 543/2011 as regards marketing standards in the fruit and vegetables sector) should be taken into account when preparing fruit for trade. According to the general marketing standard, all fruits must meet the minimum requirements, i.e. they must be: whole, healthy, clean, with a fresh appearance and correct shape, without cold, mechanical damage and sunburn, without excessive external moisture and without foreign tastes and odours. According to the guidelines of the specific standard, fruits are divided into commercial classes: Extra, 1st and 2nd.

The Extra class refers to peppers of the highest quality. The fruit must be characteristic of the variety or commercial type. In addition, they must be free from defects, with the exception of minor superficial defects, which do not affect the general appearance of the produce, preservation of quality and proper appearance in the package.

In Class 1, peppers must be of good quality with fruit specific to the variety or commercial type. The following slight defects may be allowed provided they do not affect the general appearance, quality and presentation in the package:

- slight defect in shape,
- slight silvering or damage caused by thrips, which may cover less than 1/3 of the surface of the fruit,

- slight skin defects, totalling not more than 2 cm^2 in the case of recesses, scratches, sunburn and deflections; maximum 1cm^2 in the case of defects of elongated shape and not more than 1/8 of the surface of the fruit in case of surface cracks,
- slight damage to the stalk.
- Class 2 includes peppers which do not qualify for inclusion in the higher classes but satisfy the minimum requirements. The following defects of the fruit are allowed:
- defects in shape,
- silvering or damage caused by thrips, which cover not more than 2/3 of the surface of the fruit,
- skin defects, covering a total of 4 cm or $less^2$ in the case of recesses, scratches, sunburn and deflections; maximum 2.5 cm^2 in the case of defects of elongated shape and not more than 1/4 of the surface of the fruit in case of surface cracks,
- damage to the apex not more than 1 cm^2,
- wilt not exceeding ½ of the surface,
- - damage to the stem and calyx, provided that the flesh around them is intact.

4.2. Storage

Storage is possible with fruits that are grown green, as well as partially and fully coloured. It should be remembered that coloured fruits, even under optimal conditions, can be stored shorter compared to uncoloured fruits.

Fruits should not be damaged on the skin and should be free from disease. Any scratches and mechanical damage facilitate disease infections and are the place to start rotting processes during storage. This reduces the storage period and leads to a reduction in the quality of the peppers stored. After harvesting, the peppers can be washed in water at a temperature 5°C higher than the temperature of the fruit flesh. It is very important to dry the fruit well, with particular emphasis on the place next to the stalk. One of the treatments recommended for use after harvesting is to quickly cool the pepper fruit in the refrigeration chamber by using cooled air. In the absence of refrigeration facilities, peppers can be cooled in cold water, but they must also be dried well. Otherwise, paralysis and rotting of stored pepper fruits may take place. Cooling the peppers after harvest should be done as soon as possible, preferably up to 3-4 hours after harvest.

In connection with the cultivation of various pepper varieties and the use of various pepper production methods: growing in greenhouses, cultivation in heated and unheated tunnels, low tunnels and field cultivation without cover – there is a large diversity of fruit in terms of quality on the market.

4.3. Factors affecting quality and storage durability

With a high production of peppers, to balance the market at the time of harvest, it is necessary to keep the fruit shorter or longer. After harvesting, the most important factors affecting the storage of peppers are: temperature, relative humidity and gas composition of the atmosphere. The best temperature for storing green pepper fruit is 7–8°C. Fully coloured pepper fruits are more tolerant to low temperatures, therefore, they can be stored at a temperature of 5.5-7.0°C. Even short-term storage (for a period of two days) of green pepper fruits at a temperature of 1-2°C, causes cold damage, which is cumulative and begins to develop only after receiving a specific portion of cold resulting from low temperature and its duration of operation. The first destructive changes caused by too low temperature consist in damage to cell membranes and this damage is not visible on the surface of the fruit. Visible signs of damage in the form of cavities on the surface of the fruit, followed by putrefaction spots, appear later or only after 1-3 days after transferring them to room temperature (above 15°C). Fruits with such damage are more susceptible to infectious diseases, and their commercial value is low. At optimal storage temperature, green fruit can be stored for 3–5 weeks and stained fruits for 2–3 weeks. The process of colouring green pepper fruits stored at an optimal temperature is slowed down.

The large area of the pepper fruit in relation to its weight causes the fruit to wither quickly if the relative humidity of the air during storage is not maintained at an optimal level. It is recommended to keep the relative humidity in the range of 90-95 %. In warmer climate conditions, the recommended humidity for green fruit is 85 %–90 %, and for coloured fruit 90 %–95 %. When peppers are stored at a temperature below 7–8°C and low humidity, symptoms of cold damage appear more quickly on the fruit surface. The loss of water from the pepper fruit during its storage without packaging at low relative humidity is the basic factor that shortens the storage period.

The optimal gas composition of the atmosphere, for peppers stored in a controlled atmosphere (KA) at 8°C, is: 0 % CO_2 and 3% O_2 or 2% CO_2 and 3% O_2. Such a gaseous composition of the atmosphere during refrigerated storage significantly reduces the rotting of fruit, especially after transferring them to room temperature and normal atmosphere, i.e. during retail sale. Low oxygen concentration in the storage atmosphere reduces the breathing intensity and ripening rate of the fruit, while elevated carbon dioxide levels inhibit ethylene production, chlorophyll degradation and a decrease in L-ascorbic acid content. This allows for longer maintenance of the green colour of the fruit. Differences in the optimal composition of the atmosphere gas for storing pepper may result from varietal differences, different length of storage period and varying degrees of initial maturity of the pepper fruits. When storing pepper fruits in a controlled atmosphere (CA), the relative humidity of the air should also be high, i.e. around 95 % – to minimise loss of fruit weight.

Various types of packaging made of polyethylene (PE), polypropylene (PP) or polyvinyl chloride (PVC) foil are used to reduce the loss of mass of stored peppers and preserve the high quality of the fruit. With the use of micro-perforation foil packaging, the resulting modified composition of the atmosphere inside the packaging inhibits the breathing process and protects against water loss and allows for a significant extension of the storage period. A 7 % loss in weight is assumed to be the maximum acceptable level for commercial peppers stored. The different types of foil packaging with various degrees of perforation affect the level of loss of fruit weight during storage. In the conducted studies, the storage of pepper fruits in temp. 10°C, wrapped in stretch foil in the first week, significantly reduced the level of weight loss compared to peppers stored without packaging; however, in the second and especially in the third week of storage, these differences were minimal.

4.4. Preparation for transport and sale

Pepper fruit for transport should be cooled after harvesting to a temperature of about 8^{0}C. In order to maintain a uniform temperature and relative humidity of the air at the level of approx. 90 %, it is necessary to ensure adequate air circulation in the transport containers, cars or wagons. The arrangement of the pepper in boxes and the stacking of the boxes in the transport vehicle should allow adequate ventilation, allowing the removal of heat from the mass of the product.

In accordance with Commission Delegated Regulation (EU) 2019/428, sweet peppers intended for fresh consumption, both domestically and internationally, should comply with the requirements of the specific standard (see sub-chapter 4.1). Fruits should be packed in clean boxes of standard dimensions or in other packages (e.g. cardboard boxes of 5 kg, 5 kg bags of PE perforated foil). Unit packs may also be used in which one to several pieces of fruit are packed. These are poly bags with perforation or microperforation, as well as trays that are wrapped in stretch foil after packaging. When preparing goods for trade, they should be properly labelled. It is required to indicate the name and address of the packer or consignor and the full name of the country of origin of the goods.

V. HYGIENE AND SANITARY PRINCIPLES

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

<u>Personal hygiene of employees during the harvesting and preparation for sale of pepper fruits</u>

- must not be carriers of, or have diseases transmissible through, food;
- should maintain personal cleanliness, observe hygiene rules and in particular wash hands frequently at work;
- wear clean clothing and, where necessary, protective clothing;
- apply watertight dressings to skin cuts and scratches.

The producer should provide staff working at harvesting and preparation of fruit for sale with:

- unlimited access to washbasins and toilets, cleaning products, paper towels or hand dryers, etc.;
- training in hygiene.

<u>Hygiene requirements for crops prepared for sale.</u>

A plant producer shall take appropriate measures to ensure that:

- clean water or consumption-grade water, as needed, is used to wash agricultural produce as required;
- protection of crops during and after harvesting against physical, chemical and biological pollution.

Hygiene requirements for packaging and means of transport and places for preparing crops for sale.

A producer shall take appropriate measures to ensure:

- that rooms (and equipment), means of transport and packages are clean;
- order is maintained on driveways and around buildings where merchandise is stored and prepared for trade;
- farmed and domestic animals have no access to the rooms, vehicles and packaging;
- harmful organisms (pests and organisms dangerous to humans), which may lead to contamination or pose a threat to human health, e.g. mycotoxins, are eliminated;
- hazardous waste and substances are not stored together with crops prepared for sale.

VI. GENERAL RULES FOR ISSUING INTEGRATED PRODUCTION CERTIFICATES

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

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

The certification body controls producers of plants who use Integrated Plant Production. Supervisory actions cover in particular:

- confirmation of completion of IP training;
- production in accordance with the methodologies approved by the Chief Inspector of Plant Health and Seed Inspection;
- methods and regularity of documentation,
- sampling and control of maximum residue limits for plant protection products and levels of nitrates, nitrites and heavy metals in plants and plant products;
- following hygiene and health principles.

The maximum permissible plant protection product residue content and nitrate, nitrite and heavy metal levels in plants are tested in the plants or plant products of no less than 20% of the plant producers listed in the plant producer register held by the certification body, starting with any plant producers suspected of not following integrated plant production principles. The tests are carried out in laboratories properly accredited in keeping with the provisions of the Conformity Assessment System Act of 30 August 2002 or the provisions of Regulation No 765/2008. Producers of plant products intended for human consumption should know the values of the maximum permissible pesticide residue level (Regulation (EC) No 396/2005 of the European Parliament and of the Council of 23 February 2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin. They should seek to reduce and minimise residues by extending the period between the use of pesticides and harvest.

The currently binding values of maximum permissible residue levels of pesticides in the European Community are published at: https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/start/screen/mrls.

An attestation of the use of integrated plant production shall be a certificate, which shall be issued if the plant producer complies with the following requirements:

- has completed an integrated production plant training and holds a corresponding training certificate, subject to Article 64(4),(5),(7) and (8) of the Act on Plant Protection Products;
- produces and protects 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;
- uses fertilisation based on the actual demand of plants for nutrients, determined in particular on the basis of soil or plant analyses;
- complies with plant protection requirements relating to harmful organisms, in particular those specified in the respective methodologies;
- documents the proper performance of activities related to integrated plant production;
- complies with hygiene and sanitary rules concerning the production of plants, in particular, those specified in the methodologies;
- in plant and plant product samples collected for testing, no maximum permissible residues of plant protection products and levels of nitrates, nitrites, and heavy metals have been exceeded.

Integrated plant protection certificates are issued for the period necessary for the product to be disposed of, but no longer than 12 months. Growers who have been granted a certificate attesting that they follow integrated plant production principles may use the Integrated Plant Production mark to distinguish the plants for which the certificate has been issued. The sample mark is provided by the Chief Inspector at the website of the Chief Inspectorate of Plant Health and Seed Inspection.

VII. RULES FOR DOCUMENTATION IN INTEGRATED PLANT PRODUCTION

Dr G. Gorzała

Cultivation of plants in the system of integrated plant production is inherent in the maintenance or possession of various types of documentation by the agricultural producer. An obligatory item of this documentation is the IP notebook.

Model notebooks are included in the Annex to Regulation of the Minister for Agriculture and Rural Development of 24 June 2013 on documenting activities related to integrated plant production (Journal of Laws of 2023, item 2501).

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

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

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

The application form should be completed with information such as:

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

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

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

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

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

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

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

Field plan with biodiversity-increasing elements — graphically reproduce the plan of the farm and its immediate surroundings with the proportions of the various elements. The farm plan uses the same markings as those used in the list of fields.

General information, sprayers, operators – the year in which production according to the principles of Integrated Plant Production was started is to be recorded. Then, 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 (□). Note all sprayers operators carrying out plant protection treatments in the 'Sprayer operator(s)' table. It is absolutely necessary to indicate that the training in the use of plant protection products is up to date, including the date of completion (or other qualification). In the 'Sprayers' and 'Sprayer operator(s)' tables, all devices and persons performing treatments, including those performed by a service provider, are listed.

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

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

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

Seed material (...) - complete the table by entering information about the purchased seed – variety, category, degree of qualification, quantity and proof of purchase (invoice), official label combined with plant passport, or marketing label and plant passport.

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

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

Control observations and record of plant protection treatments – the plant protection tables are the basic element of the IP Notebook. The first table 'Observations of weather conditions and plant health' is a detailed record of observations, in which we record the data indicated in the heading. In this table, the need for chemical treatment is also indicated. The next two tables are registers of plant protection treatments (agrotechnical, biological and chemical) and are closely correlated with the observation table. When carrying out this type of procedure, it is mandatory to record the name of the plant protection product or the biological or agrotechnical method applied, as well as the date and place of treatment. Table 'Other chemical treatments applied (...)' is a record of all treatments authorised for use on the crop that are not listed in the previous tables e.g. the use of desiccants. **Filling the mandatory IP notebook in the integrated plant production system fulfils the requirement to keep the above-mentioned documentation for certified crops.** The rules for documenting plant protection treatments will change on 1 January 2026 as a result of the application of the provisions of Implementing Regulation (EU) 2023/564.

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

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

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

Information relating to cleaning of machines, equipment, and hardware used in production according to the requirements of the integrated production methodology — a page in the notebook containing space for IP manufacturer's for information relating to cleaning of machinery, equipment, and hardware used in manufacturing which is required in the integrated production methodology.

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

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

VIII. LIST OF MANDATORY ACTIVITIES AND TREATMENTS IN THE INTEGRATED PAPER PRODUCTION SYSTEM

Mandatory requirements (100 % compliance, i.e. 14 / 11 points)			
Item	**Checkpoints**	**YES/NO**	**Comment**
PEPPERS IN FIELD CULTIVATION			
1.	Use of crop rotation – not growing peppers after cucurbitaceae and other Solanaceae, and in the same field no more frequently than every 4 years (see chapter II. 2.2).	❑/❑	
2.	Determination of the soil pH in the year preceding the cultivation of peppers and liming, if such a need arises from soil analysis. Cultivation is also permitted if the determination of the soil pH is carried out in the year of the beginning of the crop, provided that the soil pH is within the optimum range for the crop (see chapter II. 2.4.2)	❑/❑	
3.	Analysis of soil abundance before the start of bean cultivation, determination of fertilising needs (confirmed by the results of soil analysis) and application of optimal fertilisation (see chapter II. 2.4, 2.4.2).	❑/❑	
4.	Production of planted seedlings from 'certified' or 'standard' vegetable seeds (or sowing such seed in the field), storage of labels and proof of purchase of seed; in the case of purchase of seedlings – storage of the supplier's document and the plant passport (see Chapter II. 2.3.3 and chapter III. 3.2, 3.2.1, 3.2.2, 3.2.3).	❑/❑	
5.	Production of seedlings in peat substrates, free from pathogens and pests, attested by proof of purchase of the substrate (see chapter II. 2.3.3 and chapter III. 3.2, 3.2.1, 3.2.2, 3.2.3).	❑/❑	
6.	Inspections of pepper plantations, at least once a week, for the presence of diseases causing wilting (e.g. fusarium wilt, verticillium wilt, phytophthorosis), as well as grey mould, sclerotinia rot and alternariosis (see chapter III. 3.2, 3.2.1).-	❑/❑	
7.	Preventive/interventional control of tomato diseases only after the risk of infection has been identified by weather analysis and/or after the first symptoms of the disease have appeared (see chapter III. 3.2, 3.2.1).	❑/❑	

8.	Inclusion of non-chemical products in the pest and pathogen protection programme of plants[1]. (at least one of the treatments performed should be made with such a preparation) (see Chapter III).	❑/❑	
9.	Alternating use of plant protection products with different mechanisms of action to prevent pest resistance to pesticides (if possible) (see Chapter III).	❑/❑	
10.	Inspections of pepper plantations (at least once a week) for the presence of pests such as: aphids, spider mites, thrips (see chapter III. 3.3).	❑/❑	
11.	Monitoring the flight of butterflies with pheromone traps (minimum 2 pcs/ha) and their inspection twice a week and inspecting the occurrence of pepper damage caused by farmers' caterpillars (1 time a week) (see chapter III. 3.3).	❑/❑	
12.	Removal of plants or parts of plants (especially fruits) with symptoms of infestation by pathogens (mainly viruses) and with symptoms of physiological disturbances to an extent that prevents further growth of plants (e.g. signs of rotting) (see chapter III. 3.2, 3.2.1, 3.2.3 and chapter II. 2.9).	❑/❑	
13.	Identifying weed species in the field intended for carrot cultivation (in the year preceding the cultivation) and entering their names in the Integrated Production Notebook (see chapter III. 3.1).	❑/❑	
14.	Mowing uncultivated areas belonging to the same farm around the plantations (e.g. baulks, ditches, roads) at least 2 times a year (end of May/beginning of June and end of July/beginning of August) to prevent weeds from releasing seeds (see chapter III. 3.1, 3.1.1).	❑/❑	
PEPPER GROWN UNDER A COVER			
1.	Execution of soil affluence analysis from the land intended for the cultivation of peppers, before the beginning of cultivation, determination of fertiliser needs (confirmed by the results of soil analysis) and application of optimal fertilisation (see chapter II. 2.4, 2.4.1).	❑/❑	
2.	Production of planted seedlings from 'certified' or 'standard' vegetable seeds (or sowing such seed in the field), storage of labels and proof of purchase of seed; in the case of purchase of seedlings – storage of the	❑/❑	

[1] If such plant protection products are authorised for marketing

	supplier's document and the plant passport (see Chapter II. 2.3, 2.3.3 and chapter III. 3.2, 3.2.1, 3.2.2, 3.2.3).		
3.	Production of seedlings in peat substrates, free from pathogens and pests, attested by proof of purchase of the substrate (see chapter II, 2.3). 2.3.3 and chapter III. 3.2, 3.2.1, 3.2.2, 3.2.3).	❑/❑	
4.	Inspections of the pepper plants at least once a week for the following diseases: wilting (e.g. fusarium wilt, verticillium wilt, phytophthorosis), as well as grey mould and sclerotinia rot (see chapter III. 3.2, 3.2.1).	❑/❑	
5.	Preventive/intervention control of this disease of lettuce – only after detection of the risk of infection, based on an analysis of weather conditions and/or after the occurrence of the first disease symptoms (see chapter III. 3.2, 3.2.1).	❑/❑	
6.	Alternating use of plant protection products with different mechanisms of action to prevent pest resistance to pesticides (if possible) (see Chapter III).	❑/❑	
7.	Inspections of the cultivation of peppers, at least once a week, for the presence of movable forms of spider mites and leaf damage (see chapter III. 3.3).	❑/❑	
8.	Monitoring the occurrence of thrips and aphids using blue or yellow sticky boards (min. 1 per 100 m^2 of crop) and inspection of plants, at least once a week, for the presence of larvae and adults (see chapter III. 3.3).	❑/❑	
10.	Inclusion in the pest and pathogen protection programme of plants of non-chemicals[2] (at least one of the treatments performed should be made with such a preparation) (see chapter III).	❑/❑	
11.	Removal of plants or parts of plants (especially fruits) with symptoms of infestation by pathogens (mainly viruses) and with symptoms of physiological disturbances to an extent that prevents further growth of plants (e.g. signs of rotting) (see chapter III. 3.2, 3.2.1, 3.2.3 and chapter II. 2.9).	❑/❑	

[2] If such plant protection products are authorised for marketing

IX. CHECKLIST FOR VEGETABLES PLANTED UNDER COVER

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 Chief Inspector?	❑/❑	
2.	Does the producer have up-to-date IP training confirmed by a certificate, subject to Articles 64(4), (5), (7) and (8) of the Plant Protection Products Act?	❑/❑	
3.	Does the producer only use plant protection products included in the list of IP-recommended products?	❑/❑	
4.	Are all required documents (e.g. methodologies, notebooks) present and kept on the farm?	❑/❑	
5.	Is the IP Notebook kept correctly and up to date?	❑/❑	
6.	Does the producer systematically conduct control observations of the crops and record them in the notebook?	❑/❑	
7.	Does the producer dispose of empty packaging of plant protection products and products that are out of date in accordance with the applicable legal regulations?	❑/❑	
8.	Is chemical plant protection 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 procedures using plant protection products carried out only by persons having an up-to-date, as of the date of such procedures, certificate on the completion of training in the scope of the application of plant protection products or advisory on plant protection products, or integrated plant production, or any other document confirming the right to apply plant protection products?	❑/❑	
11.	Are the applied plant protection products approved for use in the plant?	❑/❑	
12.	Is each use of plant protection products recorded in the IP Notebook taking into account the reason, date and place of use, the area of the crops, the dosage and the amount of the spray liquid per unit of area?	❑/❑	
13.	Were the plant protection treatments carried out under appropriate conditions (optimal temperature, wind below 4 m/s)?	❑/❑	
14.	Is the rotation of the active substances of the plant protection products used for the treatments respected, if possible?	❑/❑	

15.	Does the producer limit the number of treatments and the amount of plant protection products used to a necessary minimum?	❑/❑	
16.	Does the producer have measuring devices to precisely determine the quantity of the measured plant protection 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 provisions of the label concerning the observance of precautions related to environmental protection, i.e. e.g. the observance of protective zones and safe distance from areas not used for agricultural purposes?	❑/❑	
19.	Are prevention and withdrawal periods observed?	❑/❑	
20.	Are the doses and maximum number of treatments per growing season specified on the label of the plant protection product not exceeded?	❑/❑	
21.	Are the sprayers referred to in the IP Notebook in good technical condition and are their technical inspection certificates up to date?	❑/❑	
22.	Does the producer carry out systematic calibration of the sprayer(s)?	❑/❑	
23.	Does the producer have a separate space for filling and cleaning the sprayers?	❑/❑	
24.	Does the handling of residues of the spray liquid comply with the indications on plant protection product labels?	❑/❑	
25.	Are plant protection products stored in a marked closed room in such a way as to prevent contamination of the environment?	❑/❑	
26.	Are all plant protection products stored only in their original packaging?	❑/❑	
27.	Does the IP producer observe hygienic and sanitary principles, especially those specified in the methodologies?	❑/❑	
28.	Are appropriate conditions for the development and protection of beneficial organisms ensured?	❑/❑	
	TOTAL POINTS		

Additional requirements for protected vegetables
(min. 50% compliance, i.e. 12 points)

Item	Checkpoints	Yes/No	Comment
1.	Were the plant varieties grown selected for integrated plant production?	❑/❑	
2.	Are greenhouses/polytunnels used in the IP system marked	❑/❑	

	according to the entry in the IP Notebook?		
3.	Are cultivation control devices secured and systematically supervised?	❑/❑	
4.	Did the producer perform all the necessary agrotechnical treatments in accordance with IP methodologies?	❑/❑	
5.	Does the fertilising material used (seeds, seedlings) meet quality standards and have certificates confirming that it is healthy?	❑/❑	
6.	Does the producer disinfect the substrate and production site before and after the end of the growing cycle?	❑/❑	
7.	Are mats at the entrance to the greenhouse impregnated with disinfectants?	❑/❑	
8.	Are there warning boards placed in the greenhouse or polytunnel after chemical treatment?	❑/❑	
9.	Are expired plant protection products stored separately in the plant protection products warehouse?	❑/❑	
10.	Has the equipment listed in the IP notebook been used to carry out plant protection treatments?	❑/❑	
11.	Are protective clothing and health and safety rules observed during care work, especially during spraying?	❑/❑	
12.	Are disinfecting agents used during treatments?	❑/❑	
13.	Can fertiliser application devices accurately determine the dose?	❑/❑	
14.	Is each fertiliser applied recorded with regard to its form, type, date of application, quantity, location and surface?	❑/❑	
15.	Are fertilisers and fertiliser packaging stored in a separate and specially designated room in a manner that protects the environment against contamination?	❑/❑	
16.	Does the producer protect empty PPP packaging against unauthorised access?	❑/❑	
17.	Is water of drinking water class used for washing vegetables?	❑/❑	
18.	Is the access of animals to storage, packaging and other processing areas for crops restricted?	❑/❑	
19.	Do greenhouse vents and entrance doors have protection in the form of insect-tight nets?	❑/❑	
20.	Does the producer have a properly prepared place to collect organic residues and sorted vegetables?	❑/❑	
21.	Are weeds in passages, under windowsills or cultivation tables systematically removed inside greenhouses or polytunnels?	❑/❑	
22.	Are there first-aid kits near the workplace?	❑/❑	
23.	Are hazardous areas on the farm, e.g. plant protection product storage rooms, clearly marked?	❑/❑	
24.	Does the producer use consultancy services?	❑/❑	
	TOTAL POINTS		

Recommendations (implementation min. 20 %, i.e. 3 points)			
No.	**Checkpoints**	**Yes/No**	**Comment**
1.	Are soil maps drawn up for the farm?	❑/❑	
2.	Are inorganic fertilisers stored in a clean and dry room?	❑/❑	
3.	Is a chemical analysis of organic fertilisers on the content of nutrients performed?	❑/❑	
4.	Is there an irrigation system on the farm that ensures optimal water consumption?	❑/❑	
5.	Is the irrigation water tested in a laboratory for microbiological and chemical contamination?	❑/❑	
6.	Does the lighting in the room where the plant protection products are stored make it possible to read the information on the packaging of the plant protection products?	❑/❑	
7.	Does the producer know how to proceed in the event of spill or scatter of plant protection products and do they have tools to counteract such a threat?	❑/❑	
8.	Does the producer restrict access to the keys and the warehouse in which the plant protection products are stored, to persons who do not have the authority to use them?	❑/❑	
9.	Does the producer store on the farm only plant protection products allowed for use with the plant species they cultivate?	❑/❑	
10.	Is the water used to prepare the spray liquid of the correct quality, including the correct pH?	❑/❑	
11.	Are wetting agents or adjuvants added to the spray liquid to improve the effectiveness of treatments?	❑/❑	
12.	Does the producer improve their knowledge at Integrated Plant Production meetings, courses or conferences?	❑/❑	
	TOTAL POINTS		

X. CHECKLIST FOR VEGETABLES PLANTED IN THE FIELD

Basic requirements (100% compliance, i.e. 28 points)			
No.	**Checkpoints**	**YES/NO**	**Comment**
1.	Does the producer produce and protect the crops according to detailed methodologies approved by the Chief Inspector?	❑/❑	
2.	Does the producer have up-to-date IP training confirmed by a certificate, subject to Articles 64(4), (5), (7) and (8) of the Plant Protection Products Act?	❑/❑	
3.	Does the producer only use plant protection products included in the list of IP-recommended products?	❑/❑	
4.	Are all required documents (e.g. methodologies, notebooks)	❑/❑	

	present and kept on the farm?		
5.	Is the IP Notebook kept correctly and up to date?	❑/❑	
6.	Does the producer systematically conduct control observations of the crops and record them in the notebook?	❑/❑	
7.	Does the producer dispose of empty packaging of plant protection products and products that are out of date in accordance with the applicable legal regulations?	❑/❑	
8.	Is chemical plant protection replaced by alternative methods wherever justified?	❑/❑	
9.	Where possible, is chemical plant protection conducted based on commercial threat thresholds and pest forecasting and monitoring?	❑/❑	
10.	Are procedures using plant protection products carried out only by persons having an up-to-date, as of the date of such procedures, certificate on the completion of training in the scope of the application of plant protection products or advisory on plant protection products, or integrated plant production, or any other document confirming the right to apply plant protection products?	❑/❑	
11.	Are the applied plant protection products approved for use in the plant?	❑/❑	
12.	Is each use of plant protection products recorded in the IP Notebook, taking into account the reason for use, the date and place of use and the surface area of cultivation, the dose of the preparation and the amount of spray liquid per unit of surface area?	❑/❑	
13.	Were the plant protection treatments carried out under appropriate conditions (optimal temperature, wind below 4 m/s)?	❑/❑	
14.	Is the rotation of the active substances of the plant protection products used for the treatments respected, if possible?	❑/❑	
15.	Does the producer limit the number of treatments and the amount of plant protection products used to a necessary minimum?	❑/❑	
16.	Does the producer have measuring devices to precisely determine the quantity of the measured plant protection 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 provisions of the label concerning the observance of precautions related to environmental protection, i.e. e.g. the observance of protective zones and safe distance from areas not used for agricultural purposes?	❑/❑	
19.	Are prevention and withdrawal periods observed?	❑/❑	

20.	Are the doses and maximum number of treatments per growing season specified on the label of the plant protection product not exceeded?	❑/❑	
21.	Are the sprayers referred to in the IP Notebook in 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 area for filling and washing sprayers?	❑/❑	
24.	Does the handling of usable residual liquid comply with the provisions indicated on the labels of plant protection products?	❑/❑	
25.	Are plant protection products stored in a marked closed room in such a way as to prevent contamination of the environment?	❑/❑	
26.	Are all plant protection products stored only in their original packaging?	❑/❑	
27.	Does the IP producer observe hygienic and sanitary principles, especially those specified in the methodologies?	❑/❑	
28.	Are appropriate conditions for the development and protection of beneficial organisms ensured?	❑/❑	
	TOTAL POINTS		

Additional requirements for open field vegetable crops (at least 50% compliance, i.e., 10 points)			
No.	**Checkpoints**	**YES/NO**	**Comment**
1.	Were the plant varieties grown selected for integrated plant production?	❑/❑	
2.	Is each box marked according to the entry in the IP Notebook?	❑/❑	
3.	Did the producer perform all the necessary agrotechnical treatments in accordance with IP methodologies?	❑/❑	
4.	Is the recommended catch crop used in cultivation?	❑/❑	
5.	Are steps taken on the holding to reduce soil erosion?	❑/❑	
6.	Are expired plant protection products stored separately in the plant protection products warehouse?	❑/❑	
7.	Have the procedures been conducted using sprayers specified in the IP notebook?	❑/❑	
8.	Are protective clothing and health and safety rules observed during care work, especially during spraying?	❑/❑	
9.	Are fertiliser application machines maintained in good working order?	❑/❑	

10.	Do fertiliser application machines allow for accurate dose determination?	❑/❑	
11.	Is each fertiliser applied recorded with regard to its form, type, date of application, quantity, location and surface?	❑/❑	
12.	Are fertilisers stored in a separate and specially designated room in a manner that ensures protection of the environment against contamination?	❑/❑	
13.	Does the producer protect empty PPP packaging against unauthorised access?	❑/❑	
14.	Is water of drinking water class used for washing vegetables?	❑/❑	
15.	Is the access of animals to storage, packaging and other processing areas for crops restricted?	❑/❑	
16.	Does the producer have a properly prepared place to collect organic residues and sorted vegetables?	❑/❑	
17.	Are there first-aid kits near the workplace?	❑/❑	
18.	Are hazardous areas on the farm, e.g. plant protection product storage rooms, clearly marked?	❑/❑	
19.	Does the producer use consultancy services?	❑/❑	
	TOTAL POINTS		

Recommendations (implementation min. 20 %, i.e. 3 points)			
No.	**Checkpoints**	**YES/NO**	**Comment**
1.	Are soil maps drawn up for the farm?	❑/❑	
2.	Are inorganic fertilisers stored in a clean and dry room?	❑/❑	
3.	Has a chemical analysis of organic fertilisers been carried out in terms of nutrient content?	❑/❑	
4.	Is there an irrigation system on the farm that ensures optimal water consumption?	❑/❑	
5.	Is the irrigation water tested in a laboratory for microbiological and chemical contamination?	❑/❑	
6.	Does the lighting in the room where the plant protection products are stored make it possible to read the information on the packaging of the plant protection products?	❑/❑	
7.	Does the producer know how to proceed in the event of spill or scatter of plant protection products and do they have tools to counteract such a threat?	❑/❑	
8.	Does the producer restrict access to the keys and the warehouse in which the plant protection products are stored, to persons who do not have the authority to use them?	❑/❑	
9.	Does the producer store on the farm only plant protection products allowed for use with the plant species they cultivate?	❑/❑	
10.	Is the water used to prepare the spray liquid of the correct	❑/❑	

	quality, including the correct pH?		
11.	Are wetting agents or adjuvants added to the spray liquid to improve the effectiveness of treatments?	❑/❑	
12.	Does the producer improve their knowledge at Integrated Plant Production meetings, courses or conferences?	❑/❑	
	TOTAL POINTS		

XI. LITERATURE

Adamczewska K., Kołota E. 2004. Wpływ sposobu odchwaszczania na plonowanie papryki. Folia Univ. Agric. Stetin., Agric. 95: 13-16.

Amador M. 2002. Critical period of weed control in transplanted chili pepper. Weed Research 42(3): 203 – 209. DOI:10.1046/j.1365-3180.2002.00278.x

Anyszka Z., Jarecka-Boncela A., Golian J., Kowalski A., Ptaszek M., Rybczyński D., Skubij N., Soika G., Włodarek A. 2024. Program Ochrony Roślin Warzywnych uprawianych w polu. Wyd. Virida AB ss. 396.

Anyszka Z., Golian J., Kohut M. 2012. Porównanie efektywności różnych metod ochrony przed chwastami papryki (*Capsicum annum* L.) w uprawie polowej. Prog. Plant Prot./Post. Ochr. Roślin 52 (4): 879-884.

Babadoost, M., Pavon, C., Islam, S.Z. and Tian, D. (2015). Phytophthora blight (*Phytophthora capsici*) of pepper and its management. Acta Hortic. 1105, 61-66 DOI: 10.17660/ActaHortic.2015.1105.9

Bhat R.G., Smith R.F., Koike S.T., Wu B.M., Subbarao K.V. 2003. Characterization of *Verticillium dahliae* isolates and wilt epidemics of pepper. Plant Disease 87:789-797.

Boczek J. 2001. Crop pests science. IV edition, SGGW Publishing House, Warsaw, pp. 432.

Boczek J. (ed.) 1995 – 2001. Diagnostyka szkodników roślin i ich wrogów naturalnych Volume I – IV. SGGW Publishing House, Warsaw, pp. 1637.

Buczkowska H., Michałojć Z., Nurzyńska-Wierdak R. 2016. Yield and fruit quality of sweet pepper depending on foliar application of calcium. Turkish Journal of Agriculture and Forestry, 40(2): 222-228. DOI:10.3906/tar-1501-56

Buczkowska H., 1994. Papryka – *Capsicum annuum* L. W: H. Skąpski, B. Dąbrowska (red.), Uprawa warzyw w polu, SGGW Publishing House, Warsaw

Cha S.-D., Jeon Y.-J., Ahn G.-R., In Han J., Han K.-H., Hwan Kim S. 2006. Characterization of *Sclerotinia sclerotiorum* isolated from Paprika. Mycobiology 34 (3): 154–157. DOI:10.4489/myco.2006.34.3.154

Campiglia E., Radicetti E., Mancinelli R. 2012. Weed control strategies and yield response in a pepper crop (*Capsicum annuum* L.) mulched with hairy vetch (*Vicia villosa* Roth.) and oat (*Avena sativa* L.) residues. Crop Protection, V.33: 65-73.

Deuter I., Fotyna M., Madej A. 2004. Code of Good Agricultural Practice https://iung.pl/dpr/publikacje/kodeks_dobrej_praktyki_rolniczej.pdf

Dobrzański A. 1996. Krytyczne okresy konkurencji chwastów, a racjonalne stosowanie herbicydów w uprawie warzyw. Prog. Plant Prot./Post. Ochr. Roślin, 36 (1): 110-116.

Dobrzański A. 1999. Ochrona warzyw przed chwastami. PWRiL, Warsaw, pp. 199.

Dobrzański A., Adamczewski K. 1998. Fazy rozwojowe roślin, a racjonalne zwalczanie chwastów. Prog. Plant Prot./Post. Ochr. Roślin 38 (1): 56-63.

Dobrzański A., Anyszka Z. 2006. Zastosowanie ściółki z folii biodegradowalnej do regulowania zachwaszczenia w integrowanej i ekologicznej uprawie warzyw. In: The National Popularization Conference 'Science for Practice' - Skierniewice: Inst. of Vegetables, pp. 45-51.

Dobrzański A., Anyszka Z., Pałczyński J. 2006. Problem braku odpowiednich herbicydów dla warzyw jako upraw małoobszarowych - implikacje dla praktyki. In: XLVI Scientific Session of the Institute of Plant Protection, Poznań: summaries / IPP Poznań, - pp. 36-38.

Dobrzański A., Anyszka Z., Pałczyński J. 2004. Weed biomass depending on crop species and cultivation method. Pam. Puławski, 134: 51-58.

Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (Directive 91/675/EEC). https://sip.lex.pl/akty-prawne/dzienniki-UE/dyrektywa-91-676-ewg-dotyczaca-ochrony-wod-przed-zanieczyszczeniami-67456932

Gajc-Wolska J., Skąpski H. 2002. Yield of field grown sweet pepper depending on cultivars and growing conditions. Folia Hort., Ann., 14 (1), 95-103.

Jakubas A., Cebula S., Kalisz A., Sękara S. 2013. Assessment of growth and yield of Polish sweet pepper varieties (*Capsinum annuum* L.) in the field. EPISTEME, Vol. I, 20: 341-356

Kenyon L., Kumar S., Tsai W-S., d'A Hughes J. 2014. Virus diseases of peppers (*Capsicum* spp.) and their control. Advances of Virus Research 90:297-354. DOI: 10.1016/B978-0-12-801246-8.00006-8.

Kohut M., Anyszka Z., Golian J. 2013. Zmiany w zachwaszczeniu i plonowanie wybranych gatunków warzyw w zależności od metody ochrony przed chwastami. J. Res. Appl. Agric. Eng. 58(3): 255-260.

Kołota E., Orłowski M., Biesiada A. 2007. Vegetable Growing. Publishing House UP in Wrocław, pp. 375-378, 503-511.

Kryczyński S., Weber Z. 2011. Choroby roślin uprawnych. PWRiL, Poznań, volume 2 pp. 488.

Kuchanowicz H., Przygoda B., Nadolna I., Iwanow K. 2020. Tabele składu i wartości odżywczej żywności. PZWL, Warsaw, pp. 1182.

Lipa J.J., Pruszyński S. 2010. Stan wykorzystania metod biologicznych w ochronie roślin w Polsce i na świecie. Prog. Plant Prot./Post. Ochr. Roślin 50 (3): 1033–1043.

Macias W., Szwejda J. 2006. Choroby i szkodniki papryki. Plantpress, Kraków, pp. 67.

Nurzyński J. 2008. Nawożenie roślin ogrodniczych. Wyd AR, Lublin, pp. 107-120.

Nurzyńska-Wierdak R. 2022. *Capsicum annuum* L. (bell pepper). A plant with unique bioactive compounds, nutraceutical and phytotherapeutic potential. A review. Annales Horticulturae. 31(4): 17-28 doi:10.24326/ah.2022.4.2

Oleszczak M., Ptaszek M. 2018. Przyczyny więdnięcia papryki. Warzywa, Plantpress, 5: 16–20.

Pannacci, E., Aibar J., Cirujeda A., Dobrzański A., Pardo G., Portugal J., Tei F. 2015. Weeds and weed management in peppers. 17th European Weed Research Society Symposium 'Weed management in changing environments', 23-26 June 2015, Montpellier, France

Pepper protection programme (accessed 2024) http://arc.inhort.pl/files/sor/programy_ochrony/Program_ochrony_papryki.pdf

Pruszyński S., Wolny S. 2007. Good plant protection practice. Inst. Ochr. Institute of Plant Protection, National Centre for Consultancy, Agricultural and Rural Development, Poznań Branch. Poznań, pp. 56.

Pruszyński G. 2007. Ochrona entomofauny pożytecznej w integrowanych technologiach produkcji roślinnej. Prog. Plant Protection/Post. Ochr. Roślin 47 (1): 103–107.

Pruszyński S., Dąbrowski Z.T., Hurej M., Nawrot J., Olszak R.W. 2012. Naukowe i praktyczne podstawy zwalczania szkodników w integrowanej ochronie roślin. Prog. Plant Prot./Post. Ochr. Roślin 52 (4): 843–848.

Robak J., Wiech K. 1999. Choroby i szkodniki warzyw. Wyd. Plantpress pp. 352.

Rogowska M., Sobolewski J. 2018. Vegetable Diseases and Pests. Wyd. Plantpress pp. 279-280.

Register of plant protection products authorised by the Minister for Agriculture and Agricultural Development. 2024. https://www.gov.pl/web/rolnictwo/etykiety-srodkow-ochrony-roslin. (accessed in 2024).

Regulation (EC) No 1107/2009 of the European Parliament and of the Council concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC (OJ EU L 309, 24.11.2009, p. 1).

Regulation of the Council of Ministers of 12 February 2020 adopting an 'Action Programme to reduce water pollution by nitrates from agricultural sources and to prevent further pollution' (Journal of Laws of 2023, item 244) https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20230000244/O/D20230244.pdf

Santos M., Diánez F., Sánchez-Montesinos B., Huertas V., Moreno-Gavira A., Esteban García B., Garrido-Cárdenas J.A., Gea F.J. 2023. Biocontrol of diseases caused by *Phytophthora capsici* and *P. parasitica* in pepper plants. J Fungi (Basel). 15; 9 (3): 360. doi:10.3390/jof9030360

Sierpińska A. 1997. *Bacillus thuringensis* – Stan obecny i perspektywy wykorzystania w ograniczaniu liczebności owadów liściożernych. Sylwan, 9: 63-70.

Stępowska A. 2017. Zalecenia nawozowe dla papryki w tunelach nieogrzewanych. Institute of Horticulture-NRI, Skierniewice, pp. 1-9. http://www.inhort.pl/files/program_wieloletni/PW_2015_2020_IO/spr_2017/3.2_2017_Zalecenia_nawozowe_papryka.pdf

Stępowska A. 2019. Racjonalne nawożenie papryki w uprawie gruntowej pod osłonami, Institute of Horticulture-NRI, Skierniewice, pp. 1-32. http://www.inhort.pl/files/program_wieloletni/PW_2015_2020_IO/spr_2020/3.2_Broszura_Stepowska_Racjonalne_nawozenie_papryki.pdf

Surma-Zadora M., Cieślik E., Grzych-Tuleja E., Bodzioch A. 2011. Próba znalezienia współzależności pomiędzy zawartością witaminy C a barwą papryki. Bromat. Chem. Toxicol. XLIV, 1: 17-24.

Szafirowska A., Elkner K. 2008. Yielding and fruit quality of three sweet pepper cultivars from organic and conventional cultivation. Veg. Crops Res. Bull. 69: 135-143.

Szwejda J. 2015. Pests of vegetable plants. PWN SA. Warsaw, pp. 251.

Woźnica Z. 2008. Herbologia. Podstawy biologii, ekologii i zwalczania chwastów. PWRiL, Poznań, pp. 430.

Valsikova M., Kralova J., Barkoci S. 2006. Study of some characteristics of vegetable pepper varieties. Hort. Sci. (Prague) 33(4): 153-157.

List of current varieties of peppers registered by the Centre for Testing Varieties of Cultivated Plants: https://coboru.gov.pl/Publikacje_COBORU/Listy_opisowe/LOORW%20-%20papryka%202022.pdf

Fertilisers and Fertilisation Act of 10 July 2007 (Journal of Laws of 2023, item 888) https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20230000888/O/D20230888.pdf https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20071471033/O/D20071033.pdf