MAIN INSPECTORATE FOR PLANT HEALTH AND SEED INSPECTION

DRAFT

Methodology

OF INTEGRATED PRODUCTION OF RHUBARB (*Rheum rhabarbarum* L.)

Approved
pursuant to Article 57(2)(2) of the Act of 8 March 2013 on Plant Protection Products (consolidated text in Journal of Laws of 2024, item 630, as subsequently amended)

by
the Main Inspector for Plant Health and Seed Inspection

Warsaw, 2026

Approved by

Magdalena Makowska

Institute of Horticulture – National Research Institute
Director - dr inż. Krzysztof Rutkowski

Collective paper edited by:
dr hab. Grażyna Soika, Professor at the Institute of Horticulture

Reviewers: dr hab. inż. Ewa Król. professor of the university; prof. dr hab. Adam Wojdyła

Team of authors:

dr inż. Zbigniew Anyszka
dr Joanna Golian
mgr Damian Gorzka
dr inż. Maria Grzegorzewska
dr Anna Jarecka-Boncela
dr hab. Beata Komorowska, Professor at the Institute of Horticulture
mgr inż. Artur Kowalski
mgr inż. Gerard Podedworny
dr Magdalena Ptaszek
dr hab. Grażyna Soika, Professor at the Institute of Horticulture
mgr Agata Szymczak
dr Agnieszka Włodarek

ISBN 978-83-67039-60-4

The methodology was developed as part of the special grant of the Ministry of Agriculture and Rural Development, Task 6.3. ‘Updating and developing methodologies for integrated plant protection, Integrated Plant Production, and signalling guides’.

TABLE OF CONTENTS

I. PREFACE

Integrated Plant Production (IP) is a modern system that makes sustainable use of technical and biological progress in cultivation, plant protection and fertilisation and pays particular attention to the protection of the environment and human health. A key element of IP is the application of the principles of integrated plant protection. They concern in particular the priority in the use of non-chemical methods, supplemented by chemical methods, which are used when the expected economic losses caused by pests are higher than the costs of treatments.

Among others, the application of IP is a guarantee of production of high-quality food, not exceeding permissible residues of harmful substances, less expenditure on production (fertilising based on the actual demand of plants for nutrients), 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 methodology of integrated production of rhubarb (*Rheum rhabarbarum* L.) covers all issues related to cultivation, fertilisation, site selection, crop rotation, soil preparation, sowing, irrigation, agrotechnical treatments, variety selection, as well as protection against pests and harvesting and storage. The methodology also takes into account the hygienic and sanitary principles to be observed during harvesting and preparation for the sale of agricultural products produced in the integrated plant production system and general rules for issuing certificates in integrated plant production as well as a list of mandatory activities and treatments in the integrated production system for rhubarb.

This methodology has been developed based on the results of research conducted at the Institute of Horticulture – National Research Institute and the latest data from the literature, in accordance with the requirements of integrated pest management and the guidelines of the International Organization for Biological and Integrated Control of Noxious Organisms (IOBC), as well as the International Society for Horticultural Science.

More information on registration in the integrated plant production scheme and the rules for issuing IP certificates is available on the website of the National Plant Health and Seed Inspection Service at https://www.gov.pl/web/piorin/zasady-ip.

II. ORIGIN AND DESCRIPTION OF THE SPECIES

mgr Artur Kowalski

Rhubarb is a plant most likely native to the eastern regions of Siberia, belonging to the knotweed family (*Polygonaceae*). It was introduced to Europe in the 16th century, whilst its cultivation as a vegetable dates back to the 18th century. It is currently found in the wild throughout Asia. Rhubarb is a perennial plant that develops a highly extensive root system, often reaching a depth of 150 cm (individual roots can extend to as deep as 200–250 cm). Rhubarb roots contain glycosides that have a number of medicinal properties, which is why they have been grown in China for several thousand years.

During its first 2–3 years, this plant produces a very short underground stem, which then elongates into a flowering stem reaching up to 2 m in height. The inflorescence of rhubarb is a panicle. The flowers are small and white or red in colour. The fruit, on the other hand, is a reddish-brown winged nut. The weight of a thousand seeds ranges from 9 to 14 grams, while their germination capacity is preserved for about 3 years.

Once the seeds have been released, the shoot dies off, and the stem, together with the roots and buds, forms what is known as a rhubarb crown. Rhubarb leaves have large leaf blades attached to long, thick petioles growing from a shortened stem. The leaf petioles can be green or red, just like their flesh.

The edible parts of this plant are the leaf petioles. They contain between approximately 4 % and 11.5 % of dry matter. Their energy content is only slightly higher than that of a low-calorie cucumber. The protein content is very low, reaching 0.5 %. In addition, rhubarb leaf petioles also contain minerals (calcium, iron, potassium and others), as well as vitamins A, C (20 mg per 100 g fresh weight) and B vitamins.

The advantages of rhubarb are mainly its flavour and refreshing qualities. This is because leaf petioles contain large amounts of organic acids, such as acetic, malic, citric, succinic and oxalic acids. It is precisely the latter, when consumed in large quantities, that can lead to decalcification of the body. It should be borne in mind, however, that the leaf petioles contain considerably less of this compound than the leaves, which are not even suitable as animal feed.

This vegetable is commonly grown on a smaller scale in kitchen gardens, whilst commercial plantations of this crop are usually situated on small plots of land on the outskirts of towns. Rhubarb is most commonly used to make compotes, juices and fruit tarts. The main limitation to the wider use of rhubarb in industry is its content of the aforementioned oxalic acid, which has strong oxidising properties. Oxalic acid can react with metal components (e.g. tins), which may result in the precipitation of salts that are harmful to health.

II.1 **Climate and soil requirements**

Rhubarb has low thermal requirements, which is why it is grown in many climate zones. It is a very frost-hardy plant and does not freeze to death even during cold, snowless winters. The vegetation of this species begins after the soil has thawed. With rhubarb, there is also no need to worry about the young shoots, as they can withstand frosts down to -10°C. The optimum temperature for leaf growth ranges from 12 to 15°C, whilst the minimum is 5°C. The leaves can withstand frosts down to around -3°C. Excessively high temperatures (above 25°C) can have an adverse effect on plant growth and crop quality. Temperature is also one of the main factors influencing the staining of leaf petioles, as its increase leads to the disappearance of red colour, even in varieties characterized by intense staining. In this case, the red colour is preserved only at the base of the leaf petioles.

This plant produces a large amount of biomass; consequently, it also has high water requirements. Water deficiency has a negative effect on the quality of the leaf petioles, which are less succulent, less well-coloured and fibrous. Due to the large surface area of rhubarb leaves, transpiration increases significantly, particularly in windy weather or high temperatures, which can lead to water shortages if soil moisture is too low. Excess water also negatively affects this species, because then the oxygen content in the soil decreases, resulting in rotting of the roots.

In sites located on heavy soils, this species should be planted on raised beds. The optimum groundwater level for growing rhubarb is between 1 and 1.5 metres. Although it is a plant that tolerates shade well, it produces a much better yield in areas with good light conditions.

For cultivation, it is best to choose sites situated on moist, fertile soils with a high water-holding capacity. The best soils for growing this plant include humus-rich soils, alluvial soils and black earth. In lighter soils with higher permeability and warmer soils, yields are obtained earlier, but they are lower. The optimal soil pH (pH) is between 5.7 and 7.0, so rhubarb is able to withstand greater acidification compared with most other vegetables.

III. AGRICULTURAL ENGINEERING IN INTEGRATED RHUBARB PRODUCTION

mgr Artur Kowalski

III.1 Site and crop rotation

Rhubarb, unlike most vegetable plants, is a perennial plant, so it is grown outside the crop rotation. As rhubarb has high soil moisture requirements, the best sites for growing it are those previously occupied by meadow plants. It can be grown after many crops, with the exception of alfalfa, as this increases the risk of fungal diseases affecting the root system. It is recommended that the plantation be established on fields free from nematodes and weeds.

III.2 Soil cultivation

Since rhubarb cultivation is carried out in one field for a period of 10–12 years, the site for its cultivation should be very carefully prepared. Before planting rhubarb, the soil should be deep-tilled to a depth of 40–45 cm.

Regardless of when the plantation is established, deep ploughing with a subsoiler should be carried out in the autumn, during which manure should be incorporated into the soil. It is also worth growing green manure crops before establishing a plantation, as this will further enrich the soil with nutrients and organic matter, which are essential for increasing the humus content. The depth of the arable layer should not be less than 30 cm.

If the plantation is to be established in the autumn, the soil should be tilled using a rigid-tine cultivator and a harrow, or a tillage combination should be used, which will significantly reduce the number of passes made by the tractor and other agricultural machinery. Seedlings should be planted no earlier than 6 weeks after the application of manure.

In the case of establishing plantations in the spring, the field after autumn ploughing is left in rough clods, and then the aforementioned treatments are carried out in the spring. On soils with high water levels, rhubarb should be grown on ridges or raised beds. Ridges and raised beds are formed using special machines designed for this purpose. The soil compaction achieved using these machines can last for up to three years after the treatment has been carried out. Ridges on smaller areas can also be made using ridgers used for earthing up potatoes. On light soils, a smooth roller is used after the ridger.

III.3 **Multiplication**

The main method of propagating rhubarb is vegetative propagation (by dividing the crown). Large crowns with a diameter of at least 40–50 cm from 4–6-year-old plantations are usually used to prepare seedlings. However, crowns used for forcing are not suitable. The whole process begins by digging up the crowns, which are then divided (using sharp tools such as a spade or knife) so that each section has between 1 and 3 roots and at least one bud. The seedlings should be firm and have light-coloured flesh with no hollow spaces. To qualify for use in seedling production, crowns must be free of disease. Properly prepared seedlings should weigh between 250 and 500 g. Seedlings prepared in this way should be left for about 24 hours to allow the cut end to dry out, which significantly reduces the risk of infection once the seedlings have been planted in the field.

To increase the amount of propagating material, crowns can be cut into smaller pieces (10–15 seedlings) and then planted in a seedbed. By providing them with optimal growing conditions throughout the year, it is possible to produce planting stock for the following season.

Generative propagation is mainly used in plant breeding, as the material obtained by this method is highly heterogeneous and very often differs in its characteristics from the parent plant. In this case, selection should be carried out to even out the plants. In the case of this method, the seeds are sown in rows 30 cm apart. The sowing depth for the seeds is approximately 2.5 cm. After emergence, thinning is carried out in such a way that a distance of approximately 15 cm is kept between the plants. After about 2–3 years, the plants should be transplanted to their permanent location. Harvesting on plantations of this type takes place after 4 years.

III.4 **Fertilisation**

Rhubarb is a species with high nutritional requirements. To produce a yield of 85 t/ha of leaf petioles, it draws the following from the soil: 260 kg N, 44 kg P, 415 kg K and 285 kg Ca. The optimum nutrient content of the soil prior to establishing a rhubarb crop is set out in Table 1.

Table 1. Optimal levels of macronutrients in the soil for growing rhubarb

N	**P**	**K**	**Ca**
mg/dm^3			
100 - 150	60 - 80	175 - 225	1,500 – 2,500

One of the key factors affecting the effectiveness of fertilisation is soil pH; therefore, a soil analysis should be carried out to assess this before establishing a plantation. If the results show that the value of this parameter is lower than the required minimum (the optimal soil pH value for rhubarb is in the range 5.7–7.0), liming of the soil should be carried out. Preferably, liming should be carried out in the autumn of the year preceding the crop, using the oxide form of calcium fertiliser. Liming in early spring is also permitted, although in such cases it is recommended to use lime in the form of calcium carbonate. Notably, a single dose of calcium fertilisers, calculated as CaO, must not exceed 1.0-1.5 t/ha on light soils, 2 t/ha on medium and 2.5 t/ha on heavy soils. Liming should also not be carried out simultaneously with manure application, as this leads to significant nitrogen losses. Too low soil pH, in addition to the negative effects on the nutrient uptake by plants, also limits the development and activity of the soil microbiome. It should be noted, however, that rhubarb tolerates a much lower soil pH than other vegetable species (with the exception of tomatoes).

Before establishing a plantation, organic fertiliser should be applied, for example in the form of manure, which, as well as supplying the soil with nutrients, also provides organic matter from which humus is formed. When using organic fertilisers, however, it is important to bear in mind that the maximum amount of nitrogen they can supply is 170 kg/ha per year.

Fertilisation planning should be preceded by a chemical analysis of the soil. From this, the doses of individual fertilisers are calculated. A correctly calculated dose is one that bridges the gap between the levels of individual nutrients in the soil (as determined by soil analysis) and the optimum levels for rhubarb cultivation, as set out in Table 2. The values for the lower ranges given in Table 1 refer to the optimal nutrient content on lighter types of soils, while the higher values refer to heavier soils. Mineral forms of phosphate and potash fertilisers can be applied in early autumn together with manure, whilst nitrogen fertilisation is carried out in autumn or spring, depending on when the plants are to be planted.

As rhubarb, unlike most other vegetables, is grown in the same field for many years, it also requires regular fertilisation throughout this period. It is also important to check the soil reaction; if the analysis shows a decrease in pH below the minimum value (5.7), then liming should be carried out using a calcium fertilizer in the form of carbonate. Nitrogen fertilisers are applied before the growing season begins, whilst full NPK fertilisation is carried out after harvest (Table 2).

Table 2. Approximate doses of mineral fertilisers, calculated on a pure component basis

Term	**Quantity of the ingredient in kg/ha**		
	N	**P**	**K**
Pre-vegetation	80	-	-
After the first harvest (June)	40	-	-
After the harvest (August)	40	13 - 44	50 - 166

It should be noted here that the higher doses of phosphorus and potash fertilisers indicated in Table 2 are used when high yields are achieved; conversely, when yields are lower, it is recommended to use doses from the lower end of the range. However, it should be noted that the above method of applying top-dressing is not ideal, as it is based on an estimated rather than an actual nutrient deficit. In view of the above, it is recommended that top-dressing should also be based on the results of soil analyses, since only fertilisation based on the actual content of individual elements guarantees an optimal supply of nutrients. This is also justified from both an economic and an environmental perspective, as applying excessively high doses of mineral fertilisers will not result in higher yields, and the surplus nutrients will pollute the water with biogenic elements.

III.5 **Planting**

Although rhubarb plantations can be established both in autumn and spring, better results are obtained from autumn plantings. Plants planted during this period take root more readily, start growing earlier and are stronger than those from plantations established in the spring. Spring plantings are practised mainly in areas where there are harsh winters. They are carried out very early, even in March, if conditions allow. Seedlings for spring planting are prepared in the autumn and buried to store them until spring. Seedlings should be planted deeply, so that the terminal buds are at a depth of 2–3 cm. After planting, the soil around the seedling should be pressed thoroughly. When establishing a plantation, planting material of at least ‘standard’ grade must be used (the purchase document, supplier’s document and plant passport must be retained). Planting spacing depends on the variety and soil fertility. It should be chosen in such a way that, when the plants are in full growth, their leaves cover 100 % of the soil surface. As a result, the problem of weed infestation is reduced to a minimum. The planting spacing for varieties with slower growth is 1 x 1 m, whilst for varieties with faster growth it is 1.2 x 1.2 m. For varieties with very vigorous growth, the planting spacing, depending on the soil type, is: 1.5 x 1.25 m (for poorer soils) and 2 x 2 m (for very good soils). For mechanical cultivation, a spacing of 1.2–1.65 x 2 m is used, depending on the variety. Approximately 6000 seedlings are needed for an area of 1 ha (assuming a spacing of 2 x 1 m). Rhubarb can also be grown from seed, although in practice this method is used on a smaller scale. However, this method has a number of disadvantages, which is why it is not recommended. Cultivation from seeds is troublesome, because plants often do not repeat the characteristics of the mother plant. In addition, this method of cultivation significantly delays the moment when plants reach full yield.

III.6 **Care treatments**

Weeding is one of the most important maintenance tasks; however, it is most laborious in the first year of cultivation, as the plants are not yet tall enough at this stage for their leaves to cover the entire soil surface and smother the weeds. In subsequent years, provided the crop density is adequate, manual weeding is not carried out; mechanical weeding, however, must be carried out very carefully so as not to damage the plants.

Another important maintenance task in rhubarb cultivation is the removal of flower stalks, which appear in May. This procedure should be carried out by carefully and systematically breaking them off. It should be borne in mind that any delay in removing the aforementioned shoots will result in them consuming nutrients and reducing the yield. Failure to carry out this treatment could result in a yield reduction of up to 30 % the following year.

From May to August, if soil moisture levels are insufficient, irrigation should be carried out, as rhubarb has the greatest need for water during this period. The optimum soil moisture content for this species is between 60 and 70 % field capacity. In order to correctly estimate the moisture content of the soil (without the use of special equipment), the organoleptic method can be used (Table 3).

Table 3. An organoleptic method for assessing soil moisture content

Assessment of soil moisture levels	**Available water content (% w/w)**	**Soil type**		
		Light (loose sand, slightly clayey sand)	**Medium (light or medium-grade clays)**	**Heavy (heavy clays, silt)**
Dry	0	Dry and loose, it slips through your fingers	Dusty, dry, crusted, easily crushed to a dusty state	Hard and cracked; difficult to crush into a powdery state
Weakly damp	<50	It looks like dry soil; when squeezed, it does not form a ball	It crumbles, but when squeezed in the hand, it holds together	Can be formed into a hard ball
Sufficiently moist	50 - 75	When squeezed in the hand, it can be moulded into a fragile ball	It can be shaped into a slightly malleable ball, which can then be smoothed out	It forms a malleable ball that can be stretched; it has a noticeably smooth surface
Very good	75 - 100	It forms a weak ball that easily breaks apart	It forms a highly malleable ball with a smooth surface	It forms a smooth ball that can be easily stretched
Maximum	100	When squeezed in the hand, no water leaks out, but a wet mark remains on your hand	Like light soils	Like light soils

Source: Kaniszewski S. Smoter J. 2005. Nawadnianie warzyw w uprawach polowych. Ogólnopolska konferencja naukowa. Skierniewice pp. 12-17

In the autumn, after the end of vegetation and the death of the above-ground shoots, a shallow cultivator treatment should be carried out to loosen the soil. In the case of early-season crops, it is advisable to mulch the soil with sawdust, bark or straw. This measure prevents the soil from freezing to a great depth, with the result that spring growth is significantly accelerated. Plastic sheeting, such as black plastic film or non-woven fabric, can also be used for mulching.

III.7 Methods of accelerated cultivation of rhubarb

There are two methods used for the accelerated cultivation of rhubarb: in low tunnels covered with perforated plastic film, and under a flat film. In the first case, the beds are covered with the aforementioned tunnels in early spring, which brings the harvest forward by around two weeks compared with open-field cultivation. Cultivation using this method also yields a higher and better-quality harvest.

The second method of accelerated cultivation involves covering the plantation with loose plastic film, which is sometimes not removed from the plants until the first harvest. The film must be fitted loosely enough so as not to restrict the growth of the leaves. This method is recommended for use on plantations that are 3–6 years old.

III.8 Forcing rhubarb

The forcing of rhubarb is a process that not only allows for faster harvesting, but also improves the quality of the crop. By forcing, the petioles develop a delicate flavour and texture. Two- to three-year-old crowns are used for forcing. They are harvested in autumn after the first frosts. Once dug up, the crowns should be left in the frost for 1–2 days so that they enter a state of dormancy. They are then placed in a dark room at a temperature of 12–15°C, in crates or sacks filled with growing medium. Virtually any type of room that allows the aforementioned conditions to be maintained can be used for winter forcing. During the forcing period, fertilisation is unnecessary, as the plants draw on the reserves stored in their crown. Maintenance work is mostly limited to watering and ventilating the room. After approximately 4–5 weeks, the first harvest of petioles takes place. Harvesting then continues gradually over the next two months. After forcing, the crowns can be replanted in the field.

IV. INTEGRATED PROTECTION AGAINST PESTS

dr Zbigniew Anyszka, dr Joanna Golian

Pests (pathogens, insect pests and weeds) are commonly found in crops, even in fields that are very well managed; they cause significant yield losses and reduce crop quality. The purpose of plant protection is to prevent the reduction of yields due to pests and weeds as well as the transfer and propagation of pests and weeds into areas where they were not present before. It should be carried out using an integrated approach; it is a key element of integrated crop production. Integrated Plant Protection uses natural biological and physiological mechanisms of plants, supported by the rational use of conventional, natural and biological plant protection products. The essence of integrated plant protection is to obtain high yields of good quality, under optimal cultivation conditions, in a way that does not threaten the natural environment and human health, while maintaining the profitability of production. Under integrated plant production, efforts must be made to minimise potential pest risk by means of agronomic, biological and mechanical methods, while resorting to the use of chemical methods only when necessary.

Prevention plays a very important role in the elimination of pests. The negative effects of pests on rhubarb plantations can be limited by providing appropriate conditions for growth and development of the crop, strengthening its defence mechanisms, increasing its resistance to pathogens, facilitating competition with weeds, and also by increasing the population of beneficial organisms. Preventative measures include the following: selecting a suitable site for cultivation, carefully preparing the field before establishing the plantation, choosing varieties suited to local soil, fertilisation in accordance with the crop's nutritional requirements and soil fertility, appropriate plant density, irrigation during periods of water shortage and high water demand, and careful tending of the plants throughout the growing season. Choosing a site for growing rhubarb that is free from pathogens and soil pests, as well as persistent perennial weeds, is essential.

Chemical protection of rhubarb against pests should be carried out in accordance with the principles of integrated pest management. 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 ensure that the recommended measures do not pose a risk to the natural environment, the user or the consumer, provided that they are properly applied. Helpful tools for the application of integrated pest management are: integrated pest management methodologies, economic harmfulness thresholds (where developed) or hazard thresholds, decision support systems.

In the protection of rhubarb against pests, the following principles should be observed:

- The need to carry out a treatment with a plant protection product should be determined on the basis of pest identification and infestation levels, economic injury thresholds (EITs) or action thresholds, as well as warnings of pest and disease occurrence and forecasts of weed occurrence. It should be borne in mind that thresholds of economic harmfulness are developed for specific, usually average growing conditions and cannot be uncritically adopted for specific plantations. When performing a treatment when the pest population corresponds to the threshold of economic harmfulness, there is a risk that its population will continue to increase for various reasons, and then the losses in the value of the crop may exceed the cost of performing the treatment. In order to prevent such a situation, the treatment should be performed before the pest population reaches the threshold of economic harmfulness. Such a pest size is called a harmfulness threshold and is often referred to as 80 % of the TEH value.
- Products authorised for use in the Integrated Plant Production system should be used, in particular those with a short pre-harvest interval, which remain in the soil for a short time, decompose rapidly and have the least negative impact on the crop, soil and beneficial organisms.

- Plant protection products should be used in accordance with the recommendations provided on the label and in a way that does not endanger the health of humans, animals or the environment.
- Always use products authorised for use with rhubarb and intended to control the specified pest, complying with the recommended doses, the date, and the method of use indicated on the label accompanying each product package. Before the procedure, the producer is obliged to familiarise himself with the label of the product used.

LISTS OF MEASURES FOR INTEGRATED VEGETABLE PLANT PRODUCTION published on the website of the Institute of Horticulture - National Research Institute:

https://www.inhort.pl/rosliny-warzywne-wykaz-srodkow/

and on the Pest Signalling Platform:

https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji

- Treatments with plant protection products should be carried out under optimal conditions in such a way as to maximise their biological activity, while reducing doses and lowering their consumption.
- **First and foremost, biological agents based on bacteria, fungi or viruses and plant extracts as well as products of natural origin should be selected. At least one non-chemical plant protection treatment must be performed during the growing season.**
- It is recommended to spray plantations during rain-free weather, at an acceptable wind speed and optimal air temperature. Herbicides tend to act more strongly when the temperature is higher, while some zoocides and fungicides can work less effectively or damage the plants being sprayed. If the temperature is too high during the day, then the treatment must be carried out early in the morning, when the plants are in full turgor, or in late afternoon.
- The use of plant protection products should be reduced, inter alia, by precise use only in places of infestation with pest, the addition of adjuvants to the usable liquid, the use of split doses, and adaptation of doses to the development phases of the crop and pathogens and soil conditions.
- Field mapping using modern methods (aerial photos or drones) should be used to determine the signs of damage, e.g. by pests or pathogens, the distribution of weeds in a plantation, or to perform treatments only where necessary.
- Plant protection products differ in their duration of action and persistence in the soil. This should be taken into account in the planning of subsequent plants cultivated both after the full cultivation period and in the event of an earlier liquidation of the plantation, as a result of winter damage, destruction of plants by diseases or pests and others.

- **Products with different mechanisms of action should be used alternately to prevent pests from developing resistance.** Changes in measures should also result from the need to preserve biodiversity and protect the environment.
- The spray liquid should be prepared in the amount necessary to spray the planned surface, preferably immediately before the treatment. In the event of a break in spraying, before proceeding with the procedure, the spray liquid should be mixed well with a stirrer.
- Residues of the spray liquid after treatment should be diluted with water and used on the treated area or disposed of using technical solutions ensuring biological degradation of the active substances of the plant protection products (e.g. biobed).
- After treatment, the sprayer should be thoroughly washed, preferably with special agents designed for this purpose.
- Empty packages must be rinsed three times with water and the rinsing water poured into the spray tank. Plant protection product treatments should be carried out only by persons trained by authorised organisational bodies.
- Before implementing the measure, all parties concerned must be informed of this fact.

IV.1 Prophylaxis and rules of phytosanitary hygiene in the cultivation of rhubarb

Rhubarb cultivation technology covers a series of successive cultivation and care procedures which affect pests to a varying extent. The negative effects of pests on rhubarb plantations can be limited by providing appropriate conditions for growth and development of the crop, strengthening its defence mechanisms, increasing its resistance to pathogens, facilitating competition with weeds, and also by increasing the population of beneficial organisms. The prevention of the emergence and spread of pests in crops of rhubarb entails the use of phytosanitary hygiene measures, which include:

- Careful selection of the site and the crop to be grown prior to establishing a rhubarb plantation, in order to prevent the seeds of troublesome crops and perennial weeds, or their vegetative parts (e.g. roots, tubers, stolons), from remaining in the field. Weed seeds that have fallen to the ground will lead to increased weed infestation on the plantation in subsequent years.
- **Removal and destruction of plants or their parts with symptoms of pathogen infestation (including bacteria and viruses) and pests, and with symptoms of physiological disorders to an extent that prevents further growth of plants** (deformations, decay symptoms of leaves, advanced leaf necrosis). The removal of plant residues infested by pathogens from the field is of particular importance.
- Weed seeds should be prevented from entering rhubarb plantations from neighbouring areas, and weeds should not be allowed to flower and produce seeds on field margins, slopes and roadsides. This is particularly important for those species whose seeds can be easily carried by wind or animals.
- Regular inspection of the rhubarb plantation and identification of pests, as well as determination of the intensity and area of its presence. Some pests live on the edges of plantations and it is sufficient to conduct a chemical procedure only where they appear.

- Row spacing and within-row distances should be adjusted to the variety and production intensity so as to ensure full coverage of the soil surface by rhubarb leaves during full growth.
- Appropriate fertilisation and irrigation during periods of high water demand in order to create the conditions for the formation of large leaves by rhubarb.
- Vehicles, machinery and tools used for crop cultivation and maintenance should be systematically cleaned to remove plant debris and soil, as these are major vectors for the transmission of pests, including nematodes, viruses and weed seeds.
- Predicting the occurrence of weed species in subsequent years and the severity of their infestation, based on observations carried out during the growing season of rhubarb. Knowledge of weed threats facilitates fighting them considerably.

IV.2 **Monitoring and diagnosis systems of pests and weeds**

The presence of pests at the level of threat to the cultivated plant is associated with the need to make decisions about methods and types of protection to prevent yield losses and deterioration of the quality of consumable parts. In order to conduct effective protection against pests, it is necessary to have information about their presence, i.e. the population of pests, infestation by diseases, type of weed infestation and the assessment of potential risks they cause. Such information is provided by monitoring carried out on a farm or in a specific part of the country. **Monitoring** is a regular inspection for the occurrence of pests (pathogens, pests or weeds) on plantations and the change in their numbers over a certain period of time. In order to conduct monitoring, it is necessary to identify the pest that is subject to observation, and select the method and frequency of observation. For the needs of producers, monitoring should be carried out by advisers in rhubarb-growing regions, as well as by producers of this plant themselves. Prevention and suppression of pests and weeds in rhubarb crops should be conducted based on the signalling of their appearance.

V. WEEDS

dr Zbigniew Anyszka, dr Joanna Golian, mgr Agata Szymczak

V.1 **Occurrence and harmfulness of weeds to rhubarb**

Rhubarb is a perennial plant that produces a large mass of leaves and a well-developed, deep root system. Wide and large leaves quickly cover the surface of the soil and hinder the growth of weeds. The biological characteristics of rhubarb, as well as the rapid growth rate of its leaves, determine its susceptibility to weeds. Weed infestation occurring in the first year after planting, as well as in the initial period of vegetation in subsequent years, can cause significant losses in the crop, and above all reduce the thickness of the leaf petioles and deteriorate their quality. Rhubarb is less susceptible to weed infestation than most vegetable species, particularly those grown from seed, but rhubarb beds should be kept weed-free to avoid potential yield losses.

Rhubarb is grown with wide row spacing, and numerous weeds may appear in the spaces between the rows, particularly in the first year of cultivation. Weeds grow quickly and make better use of the water and nutrients they draw from the soil than rhubarb does; this is why they pose such a serious threat to rhubarb. The level of weed infestation on rhubarb plantations varies from one growing year to the next. Weed infestation, especially in the first years after plantation, depends to a large extent on the agrotechnical condition of the field prepared for planting and the effective destruction of perennial weeds. If the field is free of perennial weeds, especially couch grass, the infestation with these onerous species in the initial years of cultivation is small, but it increases in later years. The main weeds in the initial period of rhubarb cultivation are annual dicotyledonous and monocotyledonous species. Rhubarb's high water requirements mean that weed species preferring moist conditions may appear in rhubarb plantations, such as cockspur grass, common chickweed, marsh cudweed, annual nettle, spotted knotweed, jointed knotweed (sorrel-leaved knotweed) and common ragwort, as well as perennial species such as amphibious bistort, field sow-thistle, field mint, creeping yellowcress and field horsetail. Besides species that prefer moist soils, rhubarb plantations may also be invaded by weeds found in both dry and moist habitats, such as white goosefoot, small-flowered galinsoga, shepherd's purse, red dead-nettle, black-bindweed, field mustard, redroot pigweed, wild radish and mayweed species. Rhubarb's high nutrient requirements, especially for nitrogen, favour the occurrence of nitrogen-loving weeds such as small-flowered galinsoga, white goosefoot, common chickweed, annual nettle, shepherd's purse and common ragwort. In subsequent years of rhubarb cultivation, an increasing number of perennial weeds appear, which may shorten the plantation's useful life. The presence of couch grass is particularly important, as it most often appears 3–5 years after the plantation is established and is exceptionally harmful to this crop due to its very high vigour. Perennial weeds carried by the wind may also appear on rhubarb plantations; their seeds are equipped with a pappus, which helps them to be dispersed over long distances, such as field thistle, common dandelion and field sow thistle.

Weed seeds may be dispersed by wind (anemochory), water (hydrochory), animals (zoochory), spontaneously (autochory) and humans (anthropochory). An important source of weed infestation is manure, especially poorly fermented, as many weed seeds are not destroyed in the animals' digestive tract and enter the field in the manure.

Threats to rhubarb caused by weeds result primarily from competition for water, light, nutrients, and allelopathic effects, as well as certain weed species. Allelopathic effects involve the release of chemicals that have an adverse effect on the crop. Moreover, the presence of weeds contributes to the deterioration of phytosanitary conditions on the plantation and renders treatments with plant protection products, as well as harvesting, more difficult. Weeds can also be a source of diseases and pests, which can easily spread to rhubarb. The threat to rhubarb increases during drought, since weeds consume substantial amounts of water and shade the soil which contributes to the lowering of its temperature. Strong weed infestation may cause symptoms of nutrient deficiencies. Plants are lighter in colour, lower, they may be more brittle, and the yield is reduced and of poorer quality.

Rhubarb fields are subject to annual and perennial species of weeds, and the dynamics of their emergence and species composition of weed infestation depend on, among others, the region and year of cultivation, the soil seed bank, the date of sowing, the site conditions and the weather conditions. The structure of the weed population in rhubarb planted in autumn differs from the structure in rhubarb planted in spring, which is mainly due to the thermal requirements of the weeds and the date of appearance of individual species. There are also differences in weed infestation between successive harvests. In spring-planted rhubarb, as well as in early spring during leaf emergence in cropping rhubarb, species germinating at low temperatures (2–5°C) predominate, such as white goosefoot, shepherd's purse, field pennycress, common chickweed, field mustard, black-bindweed, red dead-nettle, annual nettle, common ragwort, common fumitory, small-flowered crane's-bill, scentless mayweed and other mayweed species, whereas thermophilic species such as cockspur grass, small-flowered galinsoga, redroot pigweed and occasionally black nightshade appear in late April and May.

Many species of weeds can appear at various times during the growing season, regardless of weather conditions; consequently, a significant proportion of the weeds that appear in spring may also be found in rhubarb planted in autumn. At this time of year, the following are commonly found: small-flowered ragwort, common shepherd's purse, lamb's quarters, field mustard, bindweed, common ragwort and others.

After several years of cultivation, usually after 3–5 years, infestation by perennial weeds such as common dandelion and field sow-thistle increases, but couch grass is particularly problematic. Once it appears in the field, this species quickly takes over the spaces between the rows and the rows themselves, and its stolons even outgrow the rhubarb crowns. Mechanical treatments carried out between the rows of rhubarb encourage the growth of couch grass. For this reason, emphasis should be placed on removing plants (stolons) of this species or limiting their abundance to a level that does not threaten the sustainability of the plantation. Other perennial species are a nuisance for rhubarb producers, as they regrow quite quickly after being removed mechanically or by hand, meaning that weeding has to be repeated. Even after the harvest has ended, rhubarb must be effectively protected from weeds to prevent severe weed infestation the following year. Perennial weeds are more harmful than annual weeds because their underground parts are not completely destroyed during weeding and they quickly produce above-ground growth that rapidly increases in mass, while the weeds absorb larger amounts of nutrients necessary for survival.

Before establishing a rhubarb plantation, it is essential to remove perennial weeds such as: couch grass, field bindweed and field thistle. These weeds, including the underground part, are best combated at the end of summer or in early autumn with herbicides. Limiting the occurrence of annual weeds can be achieved by frequently tilling the soil, e.g. with a harrow, cultivator or disc harrow.

NOTE Proper protection against weeds requires knowing weed species and methods of their control. **It is the responsibility of each IP producer to correctly identify the weed species** present in the field intended for the cultivation of rhubarb as well as in the plantation of rhubarb during several years of cultivation and to record their names into the notebook of integrated production.

NOTE To reduce weed infestation, **it is recommended to mow the uncultivated areas belonging to the same holding around the plantation** (e.g. field margins, ditches, roads) at least twice a year (end of May/beginning of June and end of July / beginning of August).

V.2 Characteristics of the main weed species found in rhubarb cultivation

A. Dicot weeds

Common fumitory. Annual spring (sometimes winter) plant, 8–30 cm tall. It is propagated by seeds – 1 plant produces an average of 400 seeds, which remain viable in the soil for up to 11 years. It emerges mainly in spring, from the soil layer of up to 10 cm.

Field pansy. Annual spring or winter plant, 5–50 cm tall. It is propagated by seeds – 1 plant produces an average of 2,500 seeds, which remain viable in the soil for up to 2 years. It emerges throughout the growing season.

Field mustard. Annual spring plant, 30–60 cm tall. It is propagated by seeds – 1 plant produces an average of 1,200 seeds which maintain soil viability for up to 10 years. It emerges from spring to autumn. most often with a depth of 2-4 cm (maximum germination depth is 5-6 cm).

Chickweed. An annual, spring-germinating, winter-germinating or biennial plant, 5–40 cm tall, which most often forms dense stands. It is propagated by seeds and also by rooting in internodes. Each plant has several/over a dozen thousand seeds that remain ready to germinate for 20 (up to 50) years. It emerges all year round, even in winter. The maximum germination depth of seeds is 5-6 cm.

Common stork's-bill. Annual spring or winter plant, 10–50 cm tall. It is propagated by seeds – 1 plant produces an average of 200-600 seeds, which maintain soil viability for many years. It has spring and autumn emergence periods. It likes sandy soils, rich in nitrogen.

Common henbit. Annual spring or winter plant, 10–30 cm tall. It is propagated by seeds – 1 plant produces about 300 seeds (max. several thousand) which remain viable in the soil for 8-9 years. It emerges from March to autumn, mostly from a depth of 2-4 cm (maximum germination depth of 5-6 cm).

Lamb's quarters. An annual spring-germinating plant, 15–200 cm tall, with a mealy coating. It is propagated by seeds – 1 plant produces an average of 3,000 (up to 20,000) seeds that may maintain soil viability for a period of 40 years. It emerges throughout the growing season, most strongly in spring. The maximum germination depth of the seeds is 5 cm.

Sea mayweed. Annual spring or winter plant; under favourable conditions, it may be biennial or perennial, 20–80 cm tall. It is propagated by seeds — 1 plant produces an average of 10,000 (or more) seeds that may maintain soil viability for a period of 6-10 years. The emergence period falls in autumn and spring, with a high temperature range of 5 to 35 °C. It germinates from a depth of up to 3 cm.

Common dandelion. A perennial plant; it propagates from seeds and from divided roots. A single plant produces around 2–3 thousand seeds, which retain their ability to germinate in the soil for up to two years, or, less commonly, up to five years. Plants that are two years old or older begin their growing season in early spring, whilst seedlings usually emerge from late

May to mid-summer. Seeds germinate best at a depth of 1 cm. It flowers profusely from mid-April to the end of June, and less profusely in August and September. Insect-pollinated plant.

Field thistle. A perennial, dioecious plant, between 50 and 150 cm tall. It is propagated by root regrowth and by seeds. Emergence occurs mainly in spring, from April, when the average temperature exceeds 5°C, until June. It flowers from July to October; a single plant produces around 1,000 seeds.

Annual nettle. Annual spring plant, 20–60 cm tall. Nitrophilous species, propagated by seeds – 1 plant produces approximately 100–1,300 seeds that remain viable in the soil for several years. It emerges at different times of the year, mainly in spring, blooms from May to October. It germinates from a depth of up to 2 cm.

Speedwells. Annual plants (ivy-leaved speedwell, Persian speedwell, wall speedwell) and perennial plants (germander speedwell). Low-growing, from 5 to 35 cm in height (Persian speedwell: up to 50 cm). They are propagated by seeds (germander speedwell is propagated by rhizomes; the stem also has the ability to root). The seedlings of the ivy-leaved speedwell and the germander speedwell appear in spring and autumn, and those of Persian speedwell and wall speedwell emerge from spring to autumn.

Catchweed. Annual spring or winter plant, 30–150 cm tall. It is propagated by seeds – 1 plant produces approx. 350-600 seeds that remain viable in the soil for approx. 8 years. It emerges in spring and autumn. It has characteristic organs of attachment.

Spotted knotweed. Annual spring plant, 5 to 60 cm tall. It is propagated by seeds – 1 plant produces from 200 to about 800 seeds, which remain viable in the soil for up to 30 years. It mainly emerges in early summer, flowering from July until the first frosts.

Black-bindweed. Annual spring or winter plant, twining, 20 to 100 cm tall. It is propagated by seeds – 1 plant produces about 100–300 seeds which retain the ability to germinate in the soil for about 6 months. It emerges mainly at the end of spring and summer, sometimes until autumn, preferably from the top layer of soil. The maximum germination depth of seeds is 7-8 cm.

Field chamomile. Annual spring or winter plant, 15–50 cm tall. It is propagated by seeds – one plant produces on average 4,400 seeds (1,000-10,000), which in the soil retain their germination capacity for many years (even more than 11). It emerges from spring to autumn.

Common ragwort. Annual spring or winter plant, often overwintering, 10 to 45 cm tall. It is propagated by seeds – 1 plant produces approx. 4 thousand seeds that can germinate immediately after falling on the surface of the soil. It emerges mainly in spring, sometimes until autumn, from the depth of the soil approx. 1.5-2 cm.

Red-root amaranth. Annual spring plant, 10 to 90 cm tall. The name comes from the short bristles that cover the entire plant. It is propagated by seeds – 1 plant produces approx. 1-5 thousand seeds (or more) that remain viable in the soil up to 40 years. It emerges mainly in spring and summer, at approx. 10 °C. It germinates from a soil depth of up to 7 cm.

Shepherd's purse. Annual spring or winter plant, 5–60 cm tall. It is propagated by seeds – 1 plant produces an average of 5,000 seeds which remain viable in soil for 16-35 years. It emerges from spring until late autumn, preferably at a depth of 1–3 cm. The maximum germination depth of the seeds is 4–5 cm.

Field pennycress. Annual spring or winter plant, 15–45 cm tall. When crushed, it gives off the characteristic smell of garlic. It is propagated by seeds – 1 plant produces an average of 1,000 seeds which remain viable in soil for 30 years. Seedlings emerge from spring to autumn, and the plant may produce several generations during one growing season. The maximum germination depth of the seeds is 4–5 cm.

Potato weed. Annual spring plant with a short growing season (4–6 weeks), nitrogen-loving, 10 to 60 cm tall. It is propagated by seeds – 1 plant produces approx. 5,000-10,000 seeds which can germinate immediately after falling to the soil surface, and the maximum germination depth of the seeds is 1–2 cm. They retain their germination capacity for about 2 years. It emerges from spring to autumn. In one growing season, it can produce 2–3 generations.

B. Monocot weeds

Cockspur. Annual thermophilic spring plant, 30 to 100 cm tall. It is propagated by seeds – 1 plant produces between 200 and 1,000 caryopses which can germinate from the soil up to 10 cm. It emerges at the turn of spring and summer. The maximum germination depth of seeds is 12–14 cm.

Couch grass. A perennial, stoloniferous plant, 20 to 150 cm tall. It is propagated mainly by underground stolons, located in the top layer of the soil (approx. 20 cm), as well as through seeds. There are an average of 25–40 seeds per couch grass shoot which disperse close to the mother plant and germinate the following season in early spring, from a soil depth of up to 5 cm. The seeds remain viable in the soil for up to 4 years. During the season, up to 200 blades and stolons with a total length of up to 140 m can grow from 1 stolon bud, whereas the diameter of the area controlled by such a plant reaches 3–4 m.

Green foxtail. Annual spring plant, 10 to 40 cm tall. It creates dense clumps. It is propagated by seeds – 1 plant produces between 3 and 7 thousand grains (in yellow foxtail, from 200 to 1.5 thousand). It emerges in late spring and summer from the top of the soil when the temperature reaches a minimum of 15°C.

Table 4. Harmfulness of some major weed species to rhubarb cultivation (alphabetical list)

Species – English and Latin name	**Harmfulness**
1. Dicot weeds	
Common fumitory (*Fumaria officinalis* L.)	+
Field pansy (*Viola arvensis* L.)	+ / ++
Field mustard (*Sinapis arvensis* L.)	++
Chickweed (*Stellaria media (L.) Vill.*)	++ / +++
Common stork's-bill (*Erodium cicutarium* (L.) L'Hér.)	+
Common henbit (*Lamium amplexicaule* L.)	++
White goosefoot (*Chenopodium album* L.)	+++

Sea mayweed (*Matricaria maritima* L. subsp. *inodora* (L.), Dostál)	++
Common dandelion (*Taraxacum officinale*, F.H. Wiggers)	+ / ++
Field thistle *Cirsium arvense* (L.) Scop)	+ / ++
Annual nettle (*Urtica urens* L.)	++
Persian speedwell (*Veronica* spp.)	+
Catchweed *(Galium aparine L.)*	+ / ++
Spotted knotweed (*Persicaria maculosa* Gray)	++
Black-bindweed (*Fallopia convolvulus* (L.) Á. Löve)	++
Field chamomile (*Anthemis arvensis* L.)	++
Common ragwort (*Senecio vulgaris* L.)	++ / +++
Red-root pigweed (*Amaranthus retroflexus* L.)	++
Shepherd's purse *(Capsella bursa-pastoris (L.) Medik.)*	+++
Field pennycress (*Thlaspi arvense* L.)	++
Galingsoga (*Galinsoga parviflora* Cav.)	+++
2. Monocot weeds	
Cockspur grass (*Echinochloa crus-galli* (L.) P. Beauv.)	+++
Couch grass (*Agropyron repens* (L.) P. Beauv.)	+ / ++
Green foxtail (Setaria viridis (L.) P. Beauv.).	+

(+++) very high damage potential; (++) high damage potential; (+) low damage potential or a weed of local significance; (+ / ++) damage potential in the first year / damage potential in subsequent years

V.3 Non-chemical methods of weeding reduction

Prevention and control of weeds by agrotechnical methods

Prevention, agrotechnical treatments and other non-chemical methods are of great importance in the protection of rhubarb against weeds. Preventative measures help to keep weed infestation to a minimum, whilst non-chemical methods – particularly agrotechnical and mechanical ones – enable weeds to be effectively eliminated from plantations.

The following agronomic methods are recommended for rhubarb crops:

- It is recommended to establish rhubarb plantations on fields that are in good condition, well-tilled, with a low weed presence.
- Careful harvesting of the preceding crop before establishing a rhubarb plantation is important in order to prevent crop and weed seeds, as well as vegetative plant organs (e.g. roots and tubers), from remaining in the field. Weed seeds that have fallen to the ground are a source of increased weed infestation in the field; self-sown oilseed rape is particularly problematic.
- Fields infested with perennial weeds (e.g. field horsetail, field bindweed, creeping yellowcress, water knotweed and others) should not be selected for rhubarb growing as it is not possible to destroy these species chemically during cultivation. Especially dangerous is field horsetail because it grows deep roots and its rhizomes reach 1 to 2 m

deep into the soil. Subsoiling should not be carried out on fields infested by that species as that procedure stimulates field horsetail and other perennials to reproduce strongly. Common couch grass is also a threat; it appears on the plantation quite quickly (after 3–5 years) and spreads rapidly amongst the crops.

- A good way to limit weed infestation is to prepare and irrigate the field, which stimulates weed germination, and then, after approximately 7–10 days, to harrow the field or use a tillage unit to destroy the weed seedlings and prepare the soil for planting the crowns.
- Irrigating the plantation during periods of peak water demand helps to produce large rhubarb leaves, which makes the plants more competitive against weeds.
- Weeds cannot be allowed to flower and produce seeds as an increased repository of live seeds in the soil results in increased plantation weed infestation in the following years. This is relevant in particular for perennial weeds. Blooming weeds also attract pests that colonise rhubarb.
- Fertilisation adapted to the nutritional requirements of rhubarb and the nutrient content of the soil should be used.
- For organic fertilisation, well-fermented manure free from viable weed seeds should be used.
- Weed infestation, particularly that of annual weeds, can be reduced by applying a slow-release nitrogen-calcium mineral fertiliser in the spring. This fertilizer should be applied to moist soil, at a dose of 400–500 kg/ha.
- Before growing rhubarb, it is recommended to cultivate mixtures in the main crop, catch crops or stubble crops composed of plants such as white mustard, winter rye, phacelia, fodder radish, or buckwheat to be ploughed under as a green manure, since they help reduce potential weed infestation.

V.4 **Mechanical methods of weed control**

Mechanical treatments carried out before planting rhubarb are intended to create an appropriate soil structure, destroy weed seedlings and reduce the number of weed seeds in the soil. Mechanical treatments performed during the cultivation of rhubarb make it possible to keep weeds at a low level. Rhubarb is grown with wide row spacing, which makes it easy to carry out mechanical treatments between the rows. For mechanical weed control, passive tools with angled knives and cultivator points, usually connected to inter-row string rollers, are used. Such weeders are used for weeding between rows, and the width of the area being weeded depends on the type of weeding elements fitted to the machine, the stage of development of the rhubarb, and the precision with which the operation is carried out. However, the application of passive tools requires supplementary manual weeding in rows of plants.

New technical solutions currently applied in weeding tools provide wider possibilities for destroying weeds. Such weeders can be used in inter-rows, near the cultivated plants, and for destroying weeds in plant rows. These tools include brush weeders, finger weeders and brush-and-finger weeders.

Principles of performing mechanical procedures in rhubarb cultivation:

- The row spacing of rhubarb should match the wheel track of the tractor and the spacing of tools that will be used for mechanical treatments. The cultivation of rhubarb in a wide row spacing facilitates mechanical weed control.
- Mechanical treatments are recommended primarily during the first year after planting; in subsequent years, however, great care must be taken when carrying out these treatments so as not to damage the crop. A weeder fitted with unsuitable working parts poses a risk of damaging plants; in such cases, it is better to avoid mechanical cultivation during the growing season.
- Mechanical weed control in rhubarb cultivation can be carried out once the rhubarb leaves have emerged and weeds have started to grow (ideally from the cotyledon stage to the 2–4-leaf stage), with subsequent treatments depending on whether weeds reappear. With low weed infestation, these may be disregarded, as they accelerate germination and emergence of weeds.
- Mechanical treatments should be carried out as shallowly as possible, at a uniform depth, usually 2–4 cm when the weeds are small and more difficult to root. Procedures performed too deep are energy-intensive, may damage rhubarb's root system and lead to weed seeds capable of germination moving to the upper soil layer. Especially in the first year after planting crowns, care should be taken not to damage the apical buds of rhubarb seedlings when weeding. Therefore, mechanical treatments should be carried out at a distance of approximately 10 cm from the rhubarb crown.
- The manual and mechanical weeding may be performed after the appearance of weeds, preferably after rainfall or irrigation, once the soil has dried.
- The number of mechanical treatments depends on the dynamic of weed appearance and weather conditions. In the first year of cultivation of rhubarb, there is a need to perform 3, sometimes 4, mechanical treatments supplemented with manual weeding in rows. In fields with low weed infestation, in conditions conducive to the rapid growth of rhubarb, the number of treatments may be lower. In subsequent years of the plantation, when the rhubarb plants have grown, one mechanical weeding may be sufficient.
- After harvesting rhubarb, the soil can be loosened using a shallow-set cultivator.
- When protecting rhubarb from weeds, it is very important to mulch the soil using various types of synthetic materials or organic mulch.

V.5 **Thermal weed control**

Weeds in rhubarb can also be combated using flame (gas) weeders generating flames that burn weeds out as a result of the combustion of propane from cylinders attached to the weeder. This treatment can be carried out across the entire field before the rhubarb leaves appear; it is also possible to burn weeds in the aisles, preferably using weed burners fitted with shields to protect the crop from high temperatures, but in that case, supplementary manual weeding must be carried out. Weeds treated with high temperatures perish after several days, but this practice does not provide protection against the emergence of new weeds. It is generally accepted that flame weeding delays the next weeding by around 2, sometimes up to 3 weeks; in the case of rhubarb, this is particularly important because the rapidly growing rhubarb leaves cover the soil surface and limit weed emergence. Weed burning is quite expensive and it is recommended mainly for organic crops.

V.6 Application of mulching

Weeding in the cultivation of rhubarb can be limited by mulching the soil with light impermeable materials — black polyethylene film or non-woven fabric. Mulches limit light access to the soil surface and form a physical barrier to prevent weed germination and emergence. It also has a positive impact on the microclimate in the root zone, causing increased soil temperature and accelerating plant growth. Mulch is distributed prior to planting and the rhubarb is planted into appropriately distributed openings. Mulches can also be applied in spring to already growing plants. In this case, cut holes where the leaf buds emerge from the soil, and cover the edges of the non-woven fabric or plastic film with soil. Plastic film or non-woven fabric 1–1.5 m wide is best for mulching rhubarb. Mulching provides good protection against weeds, although weeds may grow through the slits in the film or non-woven fabric next to the plants; these can be easily removed by hand, preferably whilst they are still small. Weeds occurring between strips of non-woven fabric or film should be controlled mechanically, manually, or chemically. It is also permitted to control these weeds chemically using a sprayer fitted with a shield to prevent the spray from drifting onto the rhubarb plants. One disadvantage of mulch is its high cost. As well as synthetic mulches, organic mulches can be laid between the rows of rhubarb. To effectively prevent weeds from growing on the plantation, they should be at least 10 cm thick. It is also important that they are free of weed seeds.

V.7 Chemical weed control

Before rhubarb cultivation, perennial weeds can be controlled with herbicides containing active substances that act non-selectively (destroy all living plants) and systemically. These measures should be carried out after the previous crop has been harvested, regardless of when the rhubarb plants are planted. These measures destroy almost all species of weeds, with the exception of field horsetail, but they are mainly used for the control of couch grass and other perennial weeds. When the soil is well dressed, rhubarb can be planted into dying weeds a few days after treatment.

Plant protection products should be used according to the indications on the label and in such a way as not to endanger human health, animals or the environment.

VI. DISEASES

VI.1 Viral diseases

dr hab. Beata Komorowska

Rhubarb blotch – caused by turnip mosaic virus (TuMV)

The causal agent of the disease is widespread in rhubarb-growing regions worldwide. TuMV is transmitted by about 50 aphid species, including the peach aphid (*Myzus* (*Nectarosiphon*) *persicae* (Sulz.)). The virus is also transmitted mechanically, via the sap of infected plants, but is not transmitted via seeds. The first symptoms of infection appear on the leaves in the form of small rings, 2-10 mm in diameter, surrounded by a red border. As the disease progresses, these discolourations cover an increasingly large area of the leaf blade, causing it to turn red. Depending on the virus isolate, these symptoms may be accompanied by chlorosis of the leaf margins or lightening of the veins. The most severe symptoms of the disease are observed in the spring. In summer, as temperatures rise, these symptoms may disappear; however, once the temperature drops to around 18°C, the symptoms may reappear. The type and intensity of symptoms depend on the rhubarb variety, the virus isolate and the weather conditions. TuMV can lead to a reduction in both the quantity and quality of the crop. The losses in the cultivation of rhubarb usually reach 15%, but with severe infestation, the yield can be lower by up to 90 %.

Prevention and control. Healthy crowns should be used for planting. Throughout the growing season, crops should be inspected regularly, and diseased plants should be removed from the field as soon as possible after the onset of disease symptoms. Aphids, which are the virus vector, should be controlled; weeds that constitute the TuMV reservoir should be systematically destroyed; and crop residues should be removed from the field.

Rhubarb leaf blotch – caused by cucumber mosaic virus (CMV)

CMV is transmitted by aphids, including the peach aphid. The virus is transmitted during vegetative propagation of plants, via seeds, and mechanically, through the sap of infected plants during maintenance work. The first symptoms of the disease appear in spring – at this time, small light-green spots or a mottled pattern can be seen on individual rhubarb leaves. As the disease progresses during the summer months, the spots become more numerous; over time, they turn brown and the affected tissue eventually dies off. The leaves of infested plants are often shrivelled and twisted. The disease gradually spreads to the remaining, previously healthy leaves and can lead to the death of the entire plant.

Prevention and control. Healthy crowns should be used for planting. Conduct inspection of plantings throughout the growing season. Remove diseased plants from the field as soon as possible after the appearance of disease symptoms. Fight aphids that are vectors of the virus. Remove crop residues from the field. Remove weeds systematically, as they act as a reservoir for the virus.

Rhubarb leaf mosaic – caused by Arabis mosaic virus (ArMV)

Under natural conditions, the virus is transmitted by soil nematodes of the species *Xiphinema diversicaudatum*, during vegetative propagation of plants, and mechanically via the sap of infected plants during maintenance work. The pathogen can be transmitted via seeds, with the rate of virus transmission via this route being 10–24 %. Light green or yellow, irregular mosaic patterns are most commonly observed on the leaves of diseased plants. Some virus isolates cause chlorotic leaf spotting and yellowing of the leaf veins. Regardless of the type of discolouration associated with the presence of the virus, the leaf blades of infected plants are severely wrinkled and their edges curl downwards. Occasionally, pale streaks appear on the leaf petioles, which then become necrotic. At a high intensity of the disease, there may be a dying back of diseased leaf fragments or even entire plants. The symptoms are at their worst in early spring. In summer, as temperatures rise above 22°C, the only symptom observed is curling of the leaf blade. The growth of plants infected with ArMV is stunted. Symptoms caused by ArMV vary and depend on the virus isolate and rhubarb variety. Plants showing symptoms of infestation by ArMV may appear on the plantation individually (in random distribution) or form clusters. The random distribution suggests that the disease was introduced via infected propagating material. The appearance of clusters of diseased plants indicates the presence of nematodes in the soil that are carriers of ArMV.
Prevention and control. The soil should be tested and found to be practically free from nematodes that are vectors of viruses, or if nematodes are found, it should be demonstrated that they are free from viruses. Healthy crowns should be used for planting. Conduct inspection of plantings throughout the growing season. Remove diseased plants from the field as soon as possible after the appearance of disease symptoms. Remove crop residues from the field.

VI.2 Fungal diseases

dr Anna Jarecka-Boncela, dr Magdalena Ptaszek, dr Agnieszka Włodarek

Ascochyta blight of rhubarb **– perpetrator: *Didymella rhei* (Qian Chen & L. Cai), syn. *Ascochyta rhei* (Ellis & Everh.)**

The causal agent of the disease is widespread in rhubarb-growing regions worldwide. Small, greenish-yellow, irregular spots initially appear on the upper surface of the leaves; as the disease progresses, these spots merge to form a mosaic pattern. The centres of the spots then turn white, surrounded by a red border. Within a few days, the spots turn brown, die off and flake away, creating a 'hole'-like appearance. The pathogen does not infect the stems. The disease can cause significant losses in the rhubarb harvest. The fungus produces spores, which are carried by the wind and water. The pathogen overwinters in plant residues.

Prevention and control. Healthy crowns should be used for planting, and when harvesting rhubarb, stems with diseased leaves should be removed first.

Rhubarb blotch – perpetrator: *Ramularia rhei* (Allesch.)

The first symptoms of the disease are small, round, red spots on the upper surface of the leaf, which gradually grow larger over time. The spots then turn white or brown, with a purple rim. The pathogen also infects the leaf petioles, on which small spots initially appear. With the growth of the stem, the spots lengthen, causing lesions about 1 cm long. In the centre of the spots on both the leaves and the stems, there are white clusters of conidia. The pathogen produces spores that are spread by wind and water. The pathogen overwinters in plant residues.

Prevention and control. Healthy crowns should be used for planting. When harvesting rhubarb, the stems with infested leaves should be removed first.

Downy mildew – perpetrator: *Peronospora effusa* (Grev.) Rabenh.

It is one of the most serious diseases affecting rhubarb. The pathogen can infect plants at all stages of development. Irregular (vein-bounded) spots, which are initially chlorotic and later turn brown, appear on the upper surface of the leaf blades. In conditions of high air humidity, which favour the development of the disease, a grey and subsequently brownish-purple coating of spore stalks and sporangial spores is visible on the underside of the leaves. As the spots grow, rhubarb leaves begin to dry, and the heavily infested plants die off.

Prevention and control. A leaf sprinkling period of more than 5 hours should be strictly avoided. Healthy propagating material should be used for planting.

Rhizoctoniosis – perpetrator: *Rhizoctonia solani* (J.G. Kühn)

The perpetrator of the disease is a dangerous soil-borne pathogen found throughout the world. The pathogen winters in the form of sclerotia which can form on infested plants and in the soil. *R. solani* infects the base of the stem, which has direct contact with the ground and the crown. Rusty-brown, slightly sunken spots are observed on the infected parts of the plant. Leaking drops of amber liquid can be seen from the affected tissues. The damaged parts dry after a while, leaving chocolate-brown collapsed spots. Rhubarb leaves wilt and die.

Prevention and control. Rhubarb plantations should be established on well-drained, fertile soils. Rhubarb should not be planted immediately after other vegetable crops where rhizoctonia has occurred.

Grey mould – perpetrator *Botryotinia fuckeliana* (de Bary) Whetzel (conidial stage *Botrytis cinerea* Pers.)

The perpetrator is a typical polyphage infecting a wide range of host plants. The symptoms of the disease initially consist of watery, brownish-brown spots, which quickly spread across the affected plant tissues. In conditions of high humidity optimal for the development of the pathogen, a grey-beige, abundant, dusty coating of mycelium and conidial spores is observed on the infested tissues.

Prevention and control. The cultivation of rhubarb 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. Moderate irrigation of fields and sensible fertilisation should also be practised.

VI.3 Methods and dates of inspection

In order to ensure effective protection against diseases, information about their occurrence, degree of infestation of the plants by their perpetrators as well as an assessment of the potential risks caused by them are necessary. Such information is provided by a properly performed monitoring carried out on the farm, in a specific area, or in the entire country. **Monitoring** is a regular inspection for the occurrence of pests on plantations and the changes taking place in them over a certain time. For monitoring, it is necessary to identify the pest that is subject to observation, and select the method and frequency of observation. Monitoring of rhubarb plantations should be carried out systematically, preferably every 7–10 days. When carrying out an inspection, you should walk across the plantation diagonally or in a 'W' shape, so as to observe different parts of it, not just the edges of the field. Particular attention should be paid to: discolouration, chlorosis, deformations, spots and drying of the leaves. It is also necessary to assess whether the symptoms appear individually, in clusters or across the entire plantation, and to estimate the percentage of affected plants. If you notice the first signs of disease, you should take appropriate action, such as removing affected plants or applying the recommended control measures. The appearance of pests at a severity that threatens arable crops is the moment when a decision to perform a procedure with a plant protection product should be taken. Pest prevention and control in rhubarb crops should be carried out on the basis of pathogen alerting and, for example, the Vegetable Plant Protection Programme, prepared annually by a team of employees of the Institute of Horticulture – National Research Institute, printed in book form, available at: https://www.inhort.pl/serwis-ochrony-roslin/ochrona-roslin-rosliny warzywne/rosliny warzywne-programy-ochrony/. Communications on current pest risks also facilitate decision-making.

VI.4 Types of disease prevention

Preventing the occurrence and spread of pests in rhubarb crops involves the use of phytosanitary hygiene measures which include the following cultivation elements:

- Thorough covering of crop residues on the field accelerates their decomposition by soil microorganisms. Residues are a wintering place for certain pathogens.

- Regular observation of the rhubarb plantation and identification of pests, as well as determination of the intensity and area of its presence.

VI.5 Non-chemical methods for limiting rhubarb diseases

Agronomic method

Location of plantations. Choosing the right location is an important element in the prevention and spread of pests, mainly diseases posing an epidemic threat to rhubarb. To prevent the occurrence of rhubarb diseases, it is necessary to avoid cultivation in areas surrounded by bushes, trees, near water bodies and meadows, where morning fog may cause prolonged leaf wetting. This is the most important factor conducive to infection and the development of most pathogens of fungal, fungus-like and bacterial origin.

Carrying out mechanical soil cultivation at the appropriate time, such as deep ploughing, cultivating, harrowing or subsoiling.

Fertilisation. Proper nutrition of rhubarb plants has a significant impact on the condition of plants. Organic fertilisation with manure and compost has a beneficial effect, as beneficial micro-organisms are introduced into the soil, which stabilize the microbial balance.
Phytosanitary hygiene measures. Accurate removal of crop residues and parts of infested plants is a measure to prevent or reduce the occurrence of many pathogens, as they serve as their wintering sites.

Cultivation method

An important criterion for the selection of varieties in integrated production is their resistance or tolerance to the most dangerous diseases and low susceptibility to adverse climatic factors, the formation of a strong root system, the ability to maximize the use of nutrients, and tolerance to cold (high frost resistance). The use of the characteristics of available rhubarb varieties in cultivation allows for obtaining a commercial yield at the appropriate level.

Biological method

The biological method is successfully used in many vegetable crops under cover, and less often in field crops.

5.5. Chemical control of rhubarb diseases

Preventive method

When growing rhubarb, it is very important to take propagation material from healthy crowns or to buy seedlings *or in vitro plants*.

Intervention method

It involves the use of registered and approved fungicides for integrated production at the onset of the first symptoms of the disease on individual rhubarb plants in a specific plantation and/or in the immediate vicinity, or as indicated by alerting devices.

Table 5. Disease control on rhubarb plantations

Diseases	Times of treatments and comments
Ascochyta blight, rhizoctoniosis, grey mould, downy mildew of rhubarb	To protect rhubarb from disease, you should: • use healthy crowns for planting, • observe plant health in a given growing season at least once a week, • use correct crop rotation, • when harvesting rhubarb, first remove the stalks with affected leaves, • carefully remove post-harvest residues.

VII. PESTS

dr hab. Grażyna Soika, mgr inż. Gerard Podedworny

VII.1 Description of harmful species, prevention and control

The most common pests found in rhubarb cultivation, along with methods for controlling them, are described below. Among the harmful insects affecting rhubarb, aphids (the beetroot aphid and the peach aphid) are currently the most significant; the beetroot flea beetle is also commonly found. In addition, plantations may be damaged by other pests that occur less frequently, including dock leaf beetles (the knotweed leaf beetle and the green dock beetle), various species of moths (the potato stem borer, the silver Y moth, the sorrel cutworm and the cabbage moth) and certain heteropteran bugs (the dock bug and the fruit tree shield bug). Soil pests (grubs, wireworms, cutworms) may also pose a threat, particularly on neglected land where proper agricultural practices have not been followed.

Among the pests which are not currently found on rhubarb plantations but which may pose a threat to crops in the future, one can mention the corn borer moth (*Ostrinia nubilalis* (Hubner)) — research carried out under controlled conditions at the Institute of Horticulture in Skierniewice has confirmed its potential to cause serious damage to plants. For this reason, as part of the preventive measures, it is not recommended to establish rhubarb plantations near the cultivation of maize.

Aphids

family: Aphididae

The greatest threat to rhubarb is the beetroot aphid – *Aphis (Aphis) fabae* Scop. The peach aphid *Myzus* (*Nectarosiphon) persicae* (Sulz.), although present in much lower numbers, should also be controlled, as it is a vector of viruses that are harmful to rhubarb.

Type of damage. Aphids feed in colonies, initially on the central leaves, and later also on the undersides of older leaves and on the inflorescences. Leaves infested by pests become deformed, curling downwards. Aphids' feeding on plant sap weakens the plants, leading to a reduction in the yield of leaf petioles. Due to the multi-annual production cycle of rhubarb, the indirect harmfulness of aphids, consisting in the transmission of plant viruses by them, which may cause significant losses even with a relatively small population of these insects, is also significant.

Pest description. Adult wingless individuals of the beet aphid reach a size of 1.5 to 3 mm, and winged individuals from 1.3 to 2.5 mm. All life stages are black; the winged form is glossy, whilst the wingless form is matt with a green or brown tinge. In the final larval stage (nymph), white, waxy spots may appear on the back, forming a pattern of light-coloured stripes.

Wingless individuals of the **peach aphid** reach up to 3 mm in length, and are green, yellowish-green, or pink. In winged individuals, the head and trunk are dark, and the abdomen is olive green.

Biology. The beet aphid overwinters as eggs on spindle trees, viburnum and jasmine. When the temperature reaches around 10°C, the larvae hatch from the eggs, begin to feed, and give rise to the first 2–3 generations that develop on the winter host. Next, the winged adults emerge and fly to their summer host plants (including rhubarb). In favourable conditions, colonies quickly increase their numbers. In autumn, aphids return to their winter host, on which they lay their overwintering eggs.

Peach aphid can develop from a few to several generations in a year. It winters in the form of eggs on trees of the genus *Prunus*, primarily on peach trees and other plants, such as common wolfberry. The peach aphid can also overwinter in greenhouses on the plants grown there, developing continuously. The first generations of the peach aphid (usually 2–3) develop on the winter host plant; subsequently, in May, the winged adults migrate to the secondary host plants, which include herbaceous plants such as rhubarb. Females form colonies there, reproducing through parthenogenesis (virgin birth – without fertilisation). In autumn, winged aphids return to peach trees, where fertilised females lay their overwintering eggs.

Prevention and control. It is recommended that rhubarb crops be planted away from plants that serve as winter hosts for aphids; ideally, a distance of around 1 km should be maintained. As both aphid species are polyphagous, weeds that may serve as summer hosts for aphids should be controlled (migration of winged individuals has also been observed in summer). Balanced nitrogen fertilisation prevents excessive growth of plants with poorly developed mechanical tissues, which promotes the development of aphids. The population of aphids can be effectively limited by its numerous natural enemies, including: larvae and adult ladybirds and soldier beetles, predatory bugs of the families Miridae and Anthocoridae, larvae of Chrysopidae, Cecidomyiidae and Syrphidae, as well as parasitic wasps, e.g. aphidiine Hymenoptera of the family Braconidae. It is recommended to create conditions conducive to the occurrence of natural enemies of pests on the plantation (e.g. by installing flower strips) and to perform, as far as possible, treatments with insecticides selective for beneficial entomofauna. Nonchemical preparations should take precedence over chemical plant protection products. As aphids form colonies on the underside of leaves, when using contact or mechanical control measures, the underside of the leaves should be sprayed.

Monitoring and threat thresholds. From May to June, it is necessary to examine the plantation at weekly intervals for the presence of aphids on the rhubarb, paying attention to the heart leaves and the lower side of the leaves. The observations are made at 5 randomly selected places on a plantation, on 5 consecutive plants in a row. The threshold for a pest outbreak is defined as the presence of up to 3 aphids per plant, or more than 20 % of plants in a sample of 25 plants on which aphids are present.

Flea beetles

family: Chrysomelidae

Of the flea beetles that feed on rhubarb, the most significant is the beet flea beetle — *Chaetocnema* (*Tlanoma*) *concinna* (Th. Marsham).

Type of damage. The flea beetle adults chew small holes in rhubarb leaves. The scale of damage intensifies during a hot, dry spring.

Pest description. The flea beetle is small, reaching up to 2 mm in length. The body is black or greenish in colour, with a metallic sheen. The eggs are oblong and cream-coloured. The larvae are up to 2 mm long, creamy with a white head and three pairs of legs.

Biology. The beetles overwinter in thickets, tufts of grass and under fallen leaves. In spring, when the air temperature reaches around 10°C, they emerge from their winter hiding places and, after feeding on weeds, fly over to the plantations, where they begin to feed. From June onwards, the females lay their eggs in the topsoil, at a depth of 3–5 cm, in clutches of up to 40–60 eggs. The development of larvae takes place in the soil and lasts until the end of August. After emerging from the soil, the young beetles feed for a short while before moving to their overwintering sites.

Prevention and control. It is recommended to maintain a spatial buffer zone from other crops damaged by the beet flea beetle (beetroot and leaf beet, rhubarb, sorrel) and to control weeds (particularly those from the Chenopodiaceae, Polygonaceae and Urticaceae families), on which the pest is also found. Mechanical cultivation of the soil can destroy the places where the pest winters. In the case of high pest abundance, it is recommended to perform, as far as possible, insecticide treatments with a selective effect on useful entomofauna. Nonchemical preparations should take precedence over chemical plant protection products.

Monitoring and threat thresholds. During the growing season, inspections are carried out to look for feeding beetles or the damage they cause. When carrying out the inspection, it is recommended to examine five consecutive plants in a row at five different points whilst walking diagonally across the field. The identification of the first beetles forms the basis for the application of the eradication procedure.

Dock beetle
family: Chrysomelidae

On rhubarb, the risk is posed by the green dock beetle (*Gastrophysa viridula* (De Geer)) and the knotweed leaf beetle (*Gastrophysa polygoni* (L.)). Both of these species are widespread in the environment, as they are found not only on cultivated plants such as rhubarb, sorrel and, less commonly, buckwheat, but also on wild plants of the Polygonaceae family, including weeds of the genus *Rumex* and the genus *Polygonum*.

Type of damage. Young dock beetle larvae feed on the underside of leaves, leaving the upper layer of the cuticle intact. Over time, the tissue they leave behind dries and crumbles, and angular holes are formed in the leaves. Older larvae also feed on the upper side of the leaves. If the infestation is severe, leaf skeletonisation may occur. Adult beetles chew the margins of leaf blades.

Pest description. Green dock beetle range in length from 4 mm (males) to 7 mm (females), whilst for knotweed leaf beetle they are slightly smaller (ranging from 4 to 5 mm in length). Green dock beetle is green in colour, with shiny, iridescent, greenish-brown elytra, whilst knotweed leaf beetle has a reddish-brown pronotum and legs, and bluish-green, iridescent elytra. The females of both species can be distinguished from the males by the presence of a strongly swollen, almost spherical abdomen. The eggs are elongated in shape, initially light cream, and just before the larvae hatch, yellow to yellowish-orange. The larvae of the green leaf beetle are grey-green or brown; their bodies are clearly segmented and feature numerous spiny projections and fine bristles. The larvae of the knotweed leaf beetle, by contrast, are grey in colour (the first two stages), while the final, third stage is yellowish with black appendages.

Biology. The overwintering stage consists of beetles that appear on plants in April or May. Once they have settled on the plants, they begin to feed and mate. Females lay eggs in groups on the lower side of the leaves. The reproductive capacity of this pest is considerable — a single female green leaf beetle lays between 100 and 700 eggs, whilst a female knotweed leaf beetle lays between 600 and as many as 1,100 eggs. The larvae that hatch from the eggs feed on plants and go through three larval stages. Pupation occurs in the soil. Two to three generations develop over the course of the year.

Prevention and control. To prevent the occurrence of the leaf beetle, rhubarb plantations should be situated at a sufficient distance from other crops infested by the pest, and weeds of the Polygonaceae family, on which the pest is found, should be controlled. In the case of high pest abundance, it is recommended to perform, as far as possible, insecticide treatments with a selective effect on useful entomofauna. Biological preparations should take precedence over chemical plant protection products. In the case of smaller-scale cultivation, it is possible to collect the beetles and larvae by hand and destroy the egg clusters.

Monitoring and threat thresholds. From May onwards, you should inspect the leaves of plants for the presence of beetles, egg clusters and larvae, as well as any damage caused by the pest. When carrying out the inspection, it is recommended to examine five consecutive plants in a row at five different points whilst walking diagonally across the field. The identification of the beetles forms the basis for the application of the eradication procedure. The risk threshold for these pests has not been established.

Dock bug (*Coreus marginatus* (L.))

family: Coreidae

Type of damage. Larvae and adult bedbugs suck the juices from the leaves, buds and tops of plant growth. As a result of the pest's feeding, discolouration and necrotic spots appear on the leaves. Severely damaged leaves and buds may wither and fall off. This pest is not of great economic significance, but it can be a problem at a local level.

Pest description. Adults are oblong-oval in shape with a broad abdomen; their bodies are flattened dorsoventrally and measure 13–15 mm in length (males are smaller). The edges of the abdomen are broadened and slightly turned upwards. The body is reddish-brown in colour, with numerous spots and a lighter shade at the edges. The antennae have four segments and are reddish-orange in colour, except for the terminal segment, which is black. Between the antennae there are two small projections known as antennal tubercles. Stage 2 larvae on the abdomen have spikes, and their antennae are disproportionately large in relation to the body. The nymphs have clearly visible wing buds. The eggs are brown and elongated.

Biology. Adults overwinter. After overwintering, they feed from April to October. The females lay their eggs in late May and early June. After 3–4 weeks, the larvae hatch and go through five larval stages, emerging as adults from August onwards. One generation of the pest develops a year.

Prevention and control. Rhubarb plantations should be situated away from wetland areas (damp meadows, the banks of water bodies), where this pest is found in large numbers, and away from other crops infested by the dock bug, including sorrel, cereals, hops, sunflowers, tobacco and soft fruit plantations. Pest pressure can also be reduced by controlling its wild host plants, particularly weeds from the Polygonaceae family, ideally before they flower, as the flowers may attract the insect.

Monitoring and threat thresholds. During the growing season, it is recommended to inspect 5 consecutive plants in a row (25 plants in total) at 5 randomly selected locations in the field, looking for larvae and adult bugs, as well as signs of their feeding activity. The threat threshold has not been developed.

Rhubarb plantations may also be infested by shield bugs — the sloe bug (Carpocoris (Carpocoris) fuscispinus (Boheman)) and the southern green shield bug (Carpocoris (Carpocoris) purpuripennis (De Geer)). Both of these species are not of significant economic importance, but may cause local harm. The damage caused by these bugs on rhubarb is similar to that caused by the dock bug.

Potato stem borer (*Hydroecia micacea* (Esper))

family: Noctuidae

This species of moth posed a widespread threat to rhubarb crops at the turn of the 20th and 21st centuries, but has become less of a problem in recent years. Monitoring carried out by staff at the Institute of Horticulture in Skierniewice in 2018 did not confirm that the pest was of significant economic importance, although it may pose a threat to rhubarb plantations in some areas.

Type of damage. Caterpillars are the harmful stage. They feed on the stems and leaf petioles of rhubarb – that is, the edible parts – burrowing tunnels into them and contaminating them with their faeces. A glassy, sticky secretion oozes from the holes through which the caterpillars enter or emerge from the leaf petioles. Damaged organs often wither away. Older caterpillars also feed on rhubarb crowns. Damage acts as a gateway for infections caused by pathogens.

Pest description. Moths reach a wingspan of up to 35-50 mm. The front wings are brown in colour, slightly lighter at the ends. On the darker surface of the wings there is a characteristic bright spot in the shape of a kidney. The rear wings are grey-brown. The caterpillars are between 25 and 40 mm long; they are flesh-coloured to brown, with segments dotted with black spots, which appear to form a stripe. The head is light brown.

Biology. Eggs overwinter on the lower parts of various arable plants and weeds, very often grasses. Sometimes young caterpillars also hibernate. From late April to June, larvae hatch from winter eggs, or those that have overwintered become active. At first, they feed on grass leaves, then they gnaw on the petioles of rhubarb leaves. Once they have finished feeding, they burrow into the soil, where they pupate in July. Moths appear in August and September; after mating, the females lay their eggs. There is only one generation per season.

Prevention and control. It is recommended to control weeds on and around the plantation, in particular grasses (couch grass, bluegrass), which the caterpillars feed on immediately after hatching from their winter eggs, and weeds that flower from the end of July, which serve as a food source for adult moths. Rhubarb plantations should be sited at a sufficient distance from other crops on which the potato stem borer occurs, including potatoes, tomatoes, hops, sorrel and beetroot. In the event of damage to plants caused by the foraging of pest caterpillars, intervention spraying should be used, respecting the priority of biotechnical and biological preparations over chemical ones. In spring, it is also possible to cover the plants with soil to limit the infestation of leaf petioles and crowns by young caterpillars.

Monitoring and threat thresholds. From the end of April to June, once a week, inspect the leaf petioles of rhubarb at five randomly selected points across the field – walking diagonally across it – on five consecutive plants in a row (a total of 25 plants) to look for damage caused by the potato stem borer. From the end of July to September, it is possible to catch moths at night using insect-trapping lamps. The attractant is a mercury lamp powered by an alternating current source. In this way, both males and females are caught. Another method of catching moths is to lure them into containers filled with a mixture of honey and dark beer in a 1:1 ratio. A threat threshold has not been established.

Silver Y (*Autographa gamma* (L.))
family: Noctuidae

Type of damage. This species is particularly dangerous during periods of mass outbreaks, observed once every dozen or so years. Caterpillars feeding individually gnaw away at the tissue between the thicker veins, leaving the leaves skeletonised, and contaminate the plants with their faeces.
Pest description. Moths have a wingspan of up to 4.5 cm. The wings of the first pair are dark brown with a silvery spot in the shape of the letter gamma (γ). Eggs are spherical, white, laid in clusters. Caterpillars are green or green-yellow, approximately 4 cm in length, tapering towards the head. They move in a characteristic way, curling the middle part of the body upwards in the shape of a semicircle.
Biology. It is a migratory moth. The first generation arrives from Southern Europe, most often at the turn of May and June. Moths are active both during the day and at night. From the eggs laid on the underside of the leaves, caterpillars hatch after about two weeks and begin to feed. The pupation takes place on the underside of the leaves. Moths of the summer generation appear in July and August. In particularly favourable conditions, the development of the third generation is possible. In autumn, after the first cooling, some moths migrate south, where the pest winters.
Prevention and control. Weeds should be controlled on and around the plantation before they bloom, as adult silver Y moths feed on nectar. When the threat threshold is exceeded, pest control should be undertaken, respecting the priority of biotechnical and biological preparations over chemical ones.
Monitoring and threat thresholds. From June to September, inspect five consecutive plants in a row (25 plants in total) at five randomly selected locations on the rhubarb plantation, looking for caterpillars or egg clusters of the silver Y moth. The threshold for action is the detection of 1 caterpillar or a cluster of eggs per plant. Pheromone traps can also be used to monitor the flight of the silver Y; it is recommended that two such traps be placed at the edges of the plantation per hectare. In this case, **the warning threshold is when the first moths are caught**.

Soil pests

Soil pests found on rhubarb plantations are primarily grubs (larvae of beetles from the Melolonthidae family), wireworms (larvae of beetles from the Elateridae family), and cutworms (certain species of moths from the Noctuidae family). These are polyphagous pests, widespread across many horticultural and agricultural crops. They do not pose a widespread threat to rhubarb crops, and the damage caused by certain species, such as cutworms, is less severe than in vegetable crops grown on an annual cycle, due to the perennial nature of rhubarb production. Soil pests may pose a threat locally, particularly on plantations established on land that has been poorly managed, on former wasteland, on neglected meadows, on perennial crops, or in the vicinity of such areas.

Grubs (larvae of beetles from the Scarabaeidae family)
family: Scarabaeidae

The most damage is caused by the grubs of the following species: May beetle (Melolontha (Melolontha) melolontha (L.)), summer chafer (Amphimallon solstitiale solstitiale (L.)) and garden chafer (Phyllopertha horticola (L.)).

Description of damage. Grubs, present in the soil throughout the growing season, damage parts of underground plants by biting irregularly shaped holes in them or eating small roots whole. Damage to the tissues of underground organs can be a point of entry for pathogens. Plants with a damaged root system grow less or wither. Economically significant losses are observed in the case of a large number of grubs in the soil. Adult beetles feed on the above-ground parts of plants.

Pest description. The grubs are arched, with a white body, a thickened blue end, and a brown head. They have three pairs of legs. The larvae of the garden chafer and summer chafer reach a length of up to 20 mm, while the maybeetle larvae are larger (up to approximately 50 mm in length). May beetles are 20-30 mm long, have a black pronotum and brown wing covers, with white triangles on the sides of the abdomen. June beetles are 15-20 mm long, their elytra are light brown and covered with dense light hairs. Adult garden chafer beetles are 8-12 mm long, with a metallic green pronotum and rusty brown elytra covered with hairs.

Biology. In the garden chafer, the development of larvae lasts 1 year, in the summer chafer 2 years, and in the maybeetle most often 4 years. Larvae and beetles overwinter underground. Mass outbreaks of cockchafers occur from the end of April to the end of May, while June beetles and garden chafers appear in June and July. 3 to 6 weeks after the eggs are laid, grubs hatch which first feed in clusters and then disperse into the soil. The larvae, after reaching stage L4, which usually occurs at the end of summer or in autumn, descend deeper into the soil, where they pupate.

Monitoring and threat thresholds. The best time to assess the risk from grubs is the autumn of the year preceding the establishment of the rhubarb plantation, when it is still possible to carry out a full set of soil cultivations. To this end, 16 soil pits measuring 25×25 cm and approximately 25 cm deep are dug over an area of 1 ha, which corresponds to an area of 1 m^2. The excavated soil is then sieved through the sieve and the larvae present in it are counted. There are no established risk thresholds for rhubarb; however, as with other crops, an average of 2 grubs per soil sample taken from an area of 1 m^2 may be assumed. During the growing season, five plants should be inspected in five random places for signs of damage to the root system by grubs and the presence of larvae in the soil. **The risk threshold during this period can be taken as the presence of 1 grub per 1 r.m. of row.**

Prevention and control. The main role in combating grubs is played by agrotechnical methods. The abundance of larvae in the soil is significantly limited by shallow ploughing, deep pre-winter ploughing, and cultivation. The potential of these methods should be used before establishing a plantation, when it is still possible to carry out full soil cultivation. On existing plantations, within the limits of what is possible, soil cultivation can also be carried out. The population of grubs is also reduced by including in the crop rotation plants that are not attractive to them for food (mustard) or harmful due to the content of toxic substances in the roots (buckwheat). During the vegetation period, after exceeding the threshold of danger, the treatment of spraying or watering plants with biological agents (entomopathogenic nematodes) or preparations of plant origin (e.g. tansy extract) may be applied.

Wireworms (larvae of beetles from the Elateridae family)

family: Elateridae

Wireworms are the polyphagous larvae of various species of click beetles, including the copper click beetle (Selatosomus (Selatosomus) aeneus (L.)), the dusky wireworm (Agriotes (Agriotes) obscurus (L.)), the lined click beetle (Agriotes (Agriotes) lineatus (L.)), the common click beetle (Agriotes (Agriotes) sputator (L.)) and the black click beetle (Athous niger Fiori).

Type of damage. The damaging stage is the larvae, which feed on rhubarb crowns, gnawing holes and tunnels into them. This weakens the growth of plants and their yield. If the roots of young plants are severely damaged, they may wither. Sites damaged by wireworms can be infected by pathogens.

Pest description. The beetles have an elongated body, between 8 and 15 mm in length. The wing covers are grooved. A characteristic feature of beetles is the ability to jump when they are on their back (thanks to having a launching mechanism). The larvae of click beetles have a body covered with a hard chitinised cuticle, yellow or brown in colour. They grow to a length of 25 mm, although larvae of various sizes (at different stages of development) are most commonly found in the soil.

Biology. The development of one generation, depending on the species, takes 4-5 years. The pests overwinter in the soil as adults or larvae. In the spring, the beetles come to the surface of the soil and, after fertilisation, lay eggs in its top layer. Larvae hatch from eggs and undergo their entire development in the soil, feeding on the underground parts of plants, after which they pupate.

Monitoring and threat thresholds. An assessment of the threat from larvae should be carried out before sowing the crop, preferably in the year prior to cultivation when agro-technical control methods are still possible. For this purpose 16 samples, each measuring 25 × 25 cm and approx. 25 cm deep, forming an area of approximately 1 m^2, shall be taken from randomly selected places on a field of 1 ha. The samples taken should then be sieved and the wireworms counted. **The risk threshold is the detection of 2 wireworms on the surface of 1 m^2.**

Prevention and control. Plantations should not be established on land that has been poorly maintained, on sites that were formerly neglected meadows or plantations, or in similar locations where wireworms are often found in large numbers. It is also important to regulate water relations in the soil, as wireworms cause much more damage on moist soils than on dry ones. Treatments that significantly limit the number of wireworms include shallow tilling, deep pre-winter ploughing, and cultivating. They damage the bodies of insects and also bring larvae to the surface, where they are killed by being eaten by birds or as a result of drying. It is also recommended to include plant species that are not very attractive to wireworms in the pre-crop such as mustard or buckwheat, rape, flax, peas, and beans. In smaller areas, food traps buried in shallow pits between rows of plants can be used. Potato pieces can be used as bait. The traps should be inspected every few days and the wireworms caught should be destroyed.

Cutworms (*Agrotis* spp.)

family: Noctuidae

In vegetable crops, the most abundant is the turnip moth (*Agrotis segetum* Den. et Schiff.). The following species may also occur, though to a lesser extent: heart and dart (*Agrotis exclamationis* (L.)), spotted cutworm (*Agrotis ipsilon* (Hüfnagel)) and dark sword-grass (*Agrotis c-nigrum* (L.)). These are polyphagous pests that feed on many crops and wild plants. They are not a common threat in the cultivation of rhubarb, but they can be a problem locally.

Description of damage. Caterpillars are the harmful stage. Young caterpillars feed on the above-ground parts of plants, whilst older ones (after three moults) spend most of the day in the soil, where they damage the underground parts. At night, they come out onto the surface and bite the plants. Young plants can be eaten whole, causing so-called ‘bald patches’ to form. Older caterpillars hide in the soil during the day and feed there, damaging the underground parts of the crops.

Pest description. Moths have a wingspan of up to 45 mm. The forewings are darker than the rear ones, with a pattern of round, oval and kidney-shaped spots. The caterpillars of individual species differ in size and colouration. Turnip moth caterpillars are 45–50 mm long, dark olive with a greenish tint and darker lines along the body. The caterpillars of the heart and dart, 35–50 mm long, are brownish-grey with a light stripe running along their bodies; dark sword-grass caterpillars – up to 35 mm long, grey-green or brown; spotted cutworm caterpillars – up to 50 mm long, dark green, matt, with a reddish line on the dorsal side. The pupa is closed and reddish-brown.

Biology. Cutworms develop from 1 to 2 generations per season, depending on weather conditions. The caterpillars or pupae overwinter in the soil, at a depth of up to about 25 cm. In spring, usually in April, once the soil temperature rises above 10°C, the caterpillars leave their overwintering sites and begin feeding on plants, before burrowing into the soil to pupate. Moth flights begin at the turn of May and June. Moths are active at dusk and at night. Females lay eggs on the lower leaves of the plants or into the ground. Young caterpillars hatch after 5–15 days.

Monitoring and threat thresholds. Assessment of threat caused by cutworms is carried out before the establishment of the crop, when it is still possible to carry out a complete set of soil tillage operations, allowing the reduction of the number of wintering forms of the pest. Although no cutworm risk threshold has been established for rhubarb, it should be assumed that the presence of 6 caterpillars per 1 m^2 poses a threat to the plants, particularly in the first year after planting. In the growing season, from the beginning of May to the end of September, the flight of moths (primarily turnip moth) should be monitored using pheromone traps, with 2 traps per hectare, placed above the tops of plants. They should be monitored at least once a week, each time noting the number of moths to determine the optimal timing of the procedure. Treatment should be performed within 15 days (in warm and dry weather) up to 25 days (in colder weather) after the estimated peak of moths. In addition, during the onion growing season, inspect the plants once a week for caterpillars along a 1 r.m. length of row at five randomly selected locations in the plantation. **The detection of 1 caterpillar per r.m. of the row is the basis for carrying out the treatment.**

Prevention and control. Combating the overwintering stages of cutworms during mechanical soil cultivation treatments plays a fundamental role. In areas of high threat from cutworms, it is also possible to plough wasteland, which can be a reservoir of the pest. With a high prevalence of the pest, it is possible to consider abandoning the establishment of plantations in a given field. On an existing plantation during the growing season, once caterpillars have been detected on the plants, a spraying treatment may be carried out using registered pesticides to control the caterpillars. In reducing the number of cutworms, their natural enemies may play a role, including predatory beetles of the Carabidae family and Hymenoptera (from the Ichneumonidae Braconidae and other families) and Diptera from the Tachinidae family, whose larvae are parasitoids of caterpillars. In addition, it is recommended to destroy weeds on the plantation and in its vicinity before they bloom, as they are a source of food for adult moths.

Snails and slugs (Gastropoda)

Various species of snails, particularly slugs, can also pose a threat to rhubarb crops if they occur in significant numbers locally. They scrape away the outer layers of the skin and flesh of the leaf petioles, and contaminate them with mucus and faeces, thereby rendering them unfit for sale. They can also damage the leaf blades. They feed at night and remain hidden in shady, damp places during the day; therefore, monitoring these pests involves inspecting plants for signs of feeding damage or using baited traps.

Prevention and control. Preventing the development of snail populations consists primarily in the establishment of plantations in areas with regulated water relations. Any places that might provide suitable hiding places for snails should be removed. Destroy equipment debris and collect weeds. If you encounter problems with these pests, it is recommended that you clear ditches and scrub, and remove the cut vegetation from the plantation site. Irrigate the plantation moderately. Snail infestations are kept in check by all forms of soil cultivation, including digging, hoeing and raking. Beer traps, which have already been tested at the Institute of Horticulture in Skierniewice, are proving highly effective, both in monitoring and in mass trapping. They are installed by digging plastic containers into the ground deep enough for their rims to be level with the ground. The containers are then filled with beer. Pests attracted at night drown in the beer. These traps should be checked regularly and any snails found inside should be removed — even daily if there are large numbers of them. If snails are found in large numbers in a specific area of the plantation, barriers – such as those made of ash, sawdust or barley chaff – can be used to prevent them from spreading further. Liming the soil helps to control snail infestations. In the event of justified necessity, the use of authorised molluscicides is possible.

Table 6. Pest control on rhubarb plantations

Pests	Times of treatments and comments
Wireworms, grubs, cutworms	Treatments are performed before plantation using mechanical, phytosanitary, and biological methods.
Aphids	Spray once 3 aphids or more are found per plant, or when more than 20 % of plants in a sample of 25 are infested with aphids; this occurs from the second half of June through to July. As aphids form colonies on the underside of leaves, when using contact or mechanical control measures, the underside of the leaves should be sprayed.
Flea beetles and leaf beetles	Spray when pests appear.
Heteropteran bugs (shield bugs, dock bug)	Spray when pests appear.
Moth caterpillars (potato stem borer, silver Y moth)	Time limits for control activities vary according to the species present on the plantation. Control in the period of caterpillar hatching. The treatments should be best performed during the period of younger development stages of caterpillar (L1-L2).

VII.2 Methods of monitoring pests in rhubarb cultivation

Proper monitoring, carried out at the right time, with the appropriate frequency and using the recommended methods for a given pest, plays a key role in integrated plant production, as it allows early identification of pests threatening crops and assessment of their risk. This provides the basis for carrying out the treatments at the most appropriate time before the pest takes over the plantation and causes significant losses. Among the methods used in rhubarb pest monitoring, observation forms the basis, which can be supplemented with aids such as traps with feed or sex pheromone dispensers.

In the case of pests whose development cycle is related to the soil environment (cutworms, grubs and wireworms), observation may require digging up the soil or making excavations and taking samples. They are then sieved and the pests present are counted. Soil larvae are also visible during soil cultivation, e.g. ploughing. Another way of monitoring soil pests is to use simple baited traps. Potato or carrot pieces buried in soil at a depth of 10-15 cm every 2 m effectively attract wireworms, grubs and cutworms. However, in the case of snails, traps filled with beer are used.

Precise monitoring of the flight of some moths is enabled by pheromone traps. Currently, sex pheromone dispensers are available for silver Y and for cutworms — turnip moth, heart and dart, spotted cutworm and dark sword-grass. These traps should be inspected at least once a week, and the males caught should be counted.

VII.3 **Measures for rhubarb pest control**

Indirect pest control methods

A key role among methods of pest prevention in integrated rhubarb production is played by **proper agrotechnics**, with careful and timely soil cultivation at the forefront. Mechanical tillage, and in particular deep ploughing before establishing a plantation, combat the overwintering stages of many pests, including cutworms and harmful Scarabaeidae or Elateridae. Through the mechanical extraction of larvae to the soil surface, their susceptibility to adverse abiotic factors (drought, frost) and pressure from predators, especially birds, increases.

Balanced fertilisation serves to strengthen the mechanical tissues of plants, which makes them less susceptible to pests. Rational nitrogen fertilisation does not promote an explosive growth of plants, which reduces the pressure of aphids. Growing crops that are not hosts to rhubarb pests as a preceding crop prevents these pests from establishing themselves in the area and is a very important preventative measure. It is also important to cultivate on a given site (as a pre-crop) plants that are not an attractive source of food for pests or contain substances toxic to them (e.g. mustard and buckwheat in preventing grubs).
Weed control reduces the availability of food plants or habitats for the wintering of certain pests. This is important in the case of polyphagous pests such as flea beetles, leaf beetles, dock bug, shield bugs, but also species whose adult insects feed on nectar and are attracted by flowering plants (silver Y moth, rustic shoulder-knot, potato stem borer, cutworms).

The appropriate **location of the plantation** is also important, which should take into account potential sources of harmful insects in the immediate vicinity or places conducive to their development. In particular, it is recommended to avoid planting near beetroot and beet leaf crops, as well as sorrel, which are infested by the beet flea beetle. Rhubarb plantations should also be situated away from the winter hosts of the beetroot and peach aphids, i.e. spindle trees, viburnum, mock orange and peach orchards.

The totality of actions taken to protect natural enemies of pests, whose activity on and around the plantation prevents the excessive growth of pests, is also significant.

Direct pest control methods

Mechanical method

It can be used in the protection of crops grown in small areas. It involves collecting or removing pests from plants or their surroundings. In order to reduce the damage caused by pests, food baits can be laid out. To catch moths of the Noctuidae family, catching traps and self-traps can be used, and to protect plants against snails — beer traps and barrier fences.

Biological method

It is based primarily on creating favourable conditions for the proliferation of predatory insects and parasites that are able to significantly reduce the growth of pest populations. The overarching principle of the biological method is to assess the impact of each planned chemical treatment, especially insecticide, on beneficial organisms. In a situation where the number of pests in the field is small, the possibility of regulating its number using beneficial organisms should be assessed. For example, the appearance of black bean aphid on rhubarb at the beginning of the season may coincide with the emergence of a large population of ladybirds which will be able to significantly reduce the number of aphids without allowing excessive damage. The presence of carabidae, staphylinidae, spiders, and opiliones is particularly important in controlling the number of pests whose development is linked to the soil environment. To control moth caterpillars, priority should be given to the use of registered, commercially available biological control agents containing the bacteria *Bacillus thuringiensis*.

Also snails may prove problematic in rhubarb cultivation. They can be controlled with available biological preparations having macroorganisms – nematodes – as their active ingredient. Macro-organisms are not subject to registration in Poland. The larvae of the insect-killing nematode species – *Phasmarhabditis hermaphrodita* – penetrate the snails' bodies through their respiratory openings, infecting them.

Note that biological plant protection products must be used at least once per season (mainly before harvest), which should be confirmed by the purchase invoice of the product.

Chemical method

The decision on the use of zoocides should be based on the results of regular monitoring. In integrated production, plant protection products with the shortest withdrawal period should be used, especially in the case of interventions carried out during the period when rhubarb reaches consumer maturity, and selective preparations, i.e., those acting on a specific group of organisms.

Rules for the use of zoocides in IP

- Only plant protection products registered for rhubarb cultivation should be used, in doses and in a manner consistent with the recommendations on their label. In the integrated production of rhubarb, plant protection products listed in the list of products for integrated production in field vegetable crops (https://www.inhort.pl/rosliny-warzywne-wykaz-srodkow/) and in the Pest Signalling Platform (https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji) shall be used.

- Biological or biotechnical preparations shall have priority over chemical plant protection products.
- Where possible, the use of broad-spectrum preparations should be avoided by replacing them with agents that are selective for beneficial entomofauna.
- To prevent pests from developing resistance and the compensation of resistant forms in a given area, the rules of active substance rotation for plant protection products should be followed, i.e., avoiding the repeated use of the same substance against the same pests.
- The decision to perform a treatment with a plant protection product should be made based on the results of individual monitoring, taking into account the threat thresholds, if they have been developed for a given pest. In addition, treatments should be carried out as early as possible after the pest population has reached the threshold of harmfulness in order to ensure the most effective reduction of its abundance and to prevent its further spread within the plantation.
- Plant protection products should be used under conditions that are optimal for their effectiveness, ensuring the highest biological activity at the minimum recommended dose and reducing the risk of symptoms of phytotoxicity on plants. For most insecticides, the recommended air temperature during spraying is in the range of 18-24°C. On days with high air temperature, treatments should be performed early in the morning or in the afternoon and evening.
- Measures should be taken to prevent the drift of the working fluid to areas other than the target, in particular by spraying at the optimum wind speed. The wind speed during open air treatment must not exceed 4 m/s.

VII.4 **Actions to protect beneficial organisms**

- The decision to perform a treatment with a plant protection product should be made based on the results of individual monitoring, taking into account the threat thresholds, if they have been developed for a given pest.
- Where possible, priority should be given to selective plant protection products for beneficial fauna over broad-spectrum preparations.
- In a situation of low pest prevalence, when it does not threaten a significant reduction in yield and with a large population of its natural enemies, the treatment may be omitted.
- The use of plant protection products may be restricted solely to areas where pests occur within plantations, e.g., the periphery.
- The treatment with the plant protection product should be carried out as early as possible after the pest population has reached the threshold of danger, before its natural enemies appear in greater numbers on the plantation, for whom the preparation may be harmful.

- It is absolutely necessary to avoid the use of plant protection products during the activity periods of pollinators, and therefore to perform treatments before or after their flights. Poisoning during the spring period is particularly dangerous for wild bee populations, as females are searching for nesting sites; their death prevents the development of the next generation. In addition, honeybee hives should be protected from exposure to the working liquid of plant protection products. Unintentional or intentional acts resulting in bee poisoning are punishable by a financial penalty.
- It is recommended to take measures to provide habitats or food resources for beneficial organisms, including natural enemies of pests. These may include the establishment of flower strips with a properly selected species composition on the outskirts or directly on the plantation and the protection of field margins, mid-field refuges, and other natural or semi-natural elements of ecological infrastructure (e.g. ponds, heaps of stones).
- As part of environmental protection measures, nesting sites for wild pollinating insects should be created, such as houses for solitary bees, mason bees or bumblebee mounds at a rate of at least one per 5 ha, and in the case of larger plantations – several such structures, as well as suitable conditions for the presence of birds of prey, i.e. the installation of perches at a rate of at least one per 5 ha, and in the case of larger plantations – several such perches.

VIII. HARVESTING AND STORAGE OF RHUBARB

Dr Maria Grzegorzewska

VIII.1 Harvesting date and method

When growing rhubarb, the full harvest is carried out only when the plants are already well developed and have a strong, well-expanded root system. When grown from seed, full harvesting does not begin until the fourth year of cultivation. When sowing, you should choose reputable varieties from a reliable source. However, given the risk that the characteristics of a particular variety may not be reproduced, in large-scale production rhubarb is generally grown from seedlings obtained by dividing the crowns. With this method of cultivation, the first harvest can already be carried out in the second or third year after planting. For propagation from the crowns, the mother plants should be healthy and well developed, and each piece (new seedling) must have at least one bud. The edible part of rhubarb is the leaf petioles, which are harvested when they reach a minimum length of 25 cm. Harvesting is carried out by hand, by snapping off the leaves close to the ground, taking no more than one-third of the plant's leaves. Take care not to damage the buds and the new leaves as they emerge. A good way to do this is to twist the leaf petiole slightly at the base and pull it to one side. After breaking off the leaf, the leaf blade should be cut back to a height of up to 5 cm above the petiole. The collection is performed every 7-10 days. Rhubarb is best eaten when ripe, as that is when it is at its sweetest. The leaf petioles of mature rhubarb reach a length of 30–45 cm and a thickness of 2–2.5 cm. Do not delay the harvest of rhubarb, because the level of calcium oxalate increases in older leaves, and these substances contribute to the leaching of calcium from the human body. Furthermore, overripe petioles become stringy and spongy.

VIII.2 Cleaning and cooling

If the leaf petioles are dirty, they should be gently cleaned dry (e.g. with a soft brush) or washed in water, then thoroughly dried. Produce intended for storage should be chilled as quickly as possible in order to remove field heat, which will reduce the rate of respiration and other metabolic processes in the rhubarb. Cooling should be done up to 4 hours after harvest and, if this is not possible, within one day after harvest. It is recommended to use water cooling or forced air. Water cooling involves immersing the rhubarb in a container of ice-cold water until the temperature of the petiole flesh drops to at least 4°C. On production lines designed for water cooling, the vegetables are sprayed with ice-cold water. The time of their treatment is set by adjusting the speed of movement of the conveyor belt. Forced-air cooling is carried out in a refrigerated chamber. Packages containing rhubarb are arranged in vertical columns, which form parallel rows. These rows are then covered with polythene film (or another impermeable material) to form a tunnel. When the fan is turned on, the air from the tunnel is sucked in, forcing the cool air from the cooling chamber to flow through the rhubarb packaging. In practice, however, harvested rhubarb is most often inserted into a cooled refrigeration chamber without additional equipment where the temperature of the produce gradually decreases.

VIII.3 Conditions for and methods of storing rhubarb

Rhubarb is a highly respiratory vegetable, so it should be packed in boxes with a small capacity; ensure good air circulation in the room. The optimum storage conditions for rhubarb are a temperature of 0°C and a relative air humidity of 95–100%. In such conditions, rhubarb retains good quality for 2 to 4 weeks. Often, lower humidity is maintained in the refrigeration chambers; to protect rhubarb from wilting, it is recommended to line the boxes with polyethylene film.

VIII.4 Post-harvest treatment

The shelf life of rhubarb can be extended by wrapping the petioles in stretch film or heat-shrink film. Usually, the leaf petioles are first grouped into bunches, e.g. of 10 pieces or weighing 0.5 kg, and wrapped in suitable film.

By treating the leaf petioles after harvesting with so-called ‘hot water’ (at a temperature of 52°C) for 2 minutes, the shelf life of rhubarb on shop shelves (at 21°C) can be doubled. The use of post-harvest ozonation of rhubarb (concentration of 100 $\mu L\ L^{-1}$ for 3 min.) contributes to the reduction of natural losses of rhubarb mass during subsequent storage, as well as maintaining a higher content of vitamin C.

VIII.5 Preparation for transport and sale

When preparing rhubarb for sale, the leaf petioles are placed in crates or other containers lined with polythene film. The leaf petioles are often tied into bunches of a specific weight or number, and the bunches are then placed in crates. The whole petiole is sold; in other words, neither the base nor the remaining part of the leaf blade is trimmed. In this form, rhubarb stays fresh for longer on shop shelves and is less likely to crack.

When packing, care must be taken to ensure that the petioles in each pack are uniform; that is, they should be of the same variety, size and stage of ripeness. During the handling of goods (transport, storage and distribution), optimal temperature and relative humidity levels must be maintained. Care should also be taken to ensure that rhubarb is not transported or stored alongside climacteric fruit and vegetables, such as tomatoes, apples and pears, as these release large amounts of ethylene.

Relevant provisions refer to the labelling of the product. Each package shall bear information enabling the origin of rhubarb to be identified and specified. The name and address of the packer or consignor must be provided. When specifying the origin, the full name of the country of origin of the goods must be given. If the contents of the packaging are not visible from the outside, the name of the product must be stated.

IX. HEALTH AND HYGIENE RULES

During the harvest and preparation for sale of agricultural produce as part of an integrated plant production system, the producer shall ensure compliance with the following hygiene and health rules.

A. Personal hygiene of workers

Persons working in the harvesting and preparation of crops for sale must:

- **a.** not be a carrier of, or suffer from, diseases that can spread through food,
- **b.** maintain personal cleanliness, observe hygiene rules, and in particular wash hands frequently during work,
- **c.** wear clean clothes and, where necessary, protective clothing,
- **d.** treat injuries and abrasions with a waterproof dressing.

The plant producer must ensure that the workers that participate in the harvesting and preparation of the crop for sale have:

- **a.** unlimited access to wash basins and toilets, cleaning products, disposable towels or hand dryers, etc.,
- **b.** training in hygiene.

B. Hygiene requirements for crops prepared for sale

The plant producer must take appropriate measures to ensure:

a. the use for washing agricultural products (as required) of clean water or water intended for human consumption,
b. the protection of crops during and after harvest against physical, chemical, and biological contamination.

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

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

a. that rooms (and equipment), means of transport and packages are clean,
b. that order is maintained on driveways and around buildings where merchandise is stored and prepared for trade,
c. that farm and domestic animals are not allowed access to rooms, vehicles and packages,
d. the elimination of harmful organisms (plant pests and organisms dangerous to humans) that may cause pollution or threats to human health, e.g. mycotoxins,
e. that hazardous waste and substances are not stored together with crops prepared for sale.

X. LIST OF MANDATORY PROCEDURES AND TREATMENTS IN THE SYSTEM OF INTEGRATED RHUBARB PRODUCTION

Mandatory requirements (100 % compliance, i.e. 13 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	Rhubarb should not be grown on a site where lucerne has previously been grown (see Chapter III. 3.1).	❑/❑	
2.	Regardless of the date of establishment of the plantation, deep ploughing with a subsoiler must be carried out in the autumn (see Chapter III. 3.2).	❑/❑	
3.	Determination of soil pH, in the year prior to rhubarb cultivation, confirmed by an analysis, and implementation of liming if necessary (see Chapter III. 3.4).	❑/❑	
4.	Analysis of soil abundance before the start of the cultivation of rhubarb, determination of fertilising needs (confirmed by the results of soil analysis) and application of optimal fertilisation (see Chapter III. 3.4).	❑/❑	

5	Production of seedlings from planting stock of at least ‘standard’ grade. When purchasing seeds, seedlings or crowns, you must keep the proof of purchase, the supplier’s document and the plant passport (see Chapter III. 3.5).	❑/❑	
6	Mowing of uncultivated areas belonging to the same farm around the plantation (e.g. boundary strips, ditches, roads), at least twice a year (end of May/beginning of June and end of July/beginning of August) in order to prevent the release of seeds by weeds (see Chapter V, 5.1).	❑/❑	
7.	Monitoring of plantations for the presence of the following diseases: viral diseases, grey mould, ascochyta blight, downy mildew. The frequency and method of monitoring should be carried out in accordance with the described guidelines (see Chapter VI. 6.1; 6.2; 6.3).	❑/❑	
8	Removal of plants or parts thereof with symptoms of pathogen infestation to an extent that prevents further growth of the plants (deformations, symptoms of leaf rot, advanced leaf necrosis) (see chapter VI. 5.5.1).	❑/❑	
9.	Soil testing prior to establishing a plantation to check for the presence of soil-feeding pests (grubs, wireworms, cutworm larvae). Once their presence is established, eradicate them using a mechanical method (ploughing or tilling the soil with machines with sharp tillage elements) or biological method (entomopathogenic nematodes) or plant preparations see chapter VII. 7.1, 7.3.).	❑/❑	
10.	Regular monitoring from early spring for pests such as aphids, flea beetles and moth caterpillars (potato stem borer, silver Y moth and cutworms). The frequency and method of monitoring should be carried out in accordance with the described guidelines (see Chapter VII. 7.1, 7.2).	❑/❑	
11	Inclusion of non-chemical preparations in the control of aphids and moth caterpillars (at least one of the treatments should be carried out with such a preparation) (see Chapter VII. 7.1).	❑/❑	
12.	Creating suitable conditions for the presence of birds of prey, i.e. setting the resting poles in the amount of at least 1 per 5 ha, and in the case of larger plantations – several units (see Chapter VII. 7.4).	❑/❑	
13.	Placement of ‘houses’ for mason bees or mounds for bumblebees at a frequency of at least 1 per 5 ha, and in the case of larger plantations – several units (see Chapter VII. 7.4).	❑/❑	

	Total points		

Note:
The carrying out of all the obligatory actions and treatments under integrated production must be documented in the Integrated Production Notebook

XI. CHECKLIST FOR FIELD-GROWN VEGETABLES

Basic requirements (100% compliance, i.e. 27 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	Does the producer produce and protect the crops according to detailed methodologies approved by the Main Inspector?	❑/❑	
2.	Does the producer have up-to-date IP training attested by a certificate?	❑/❑	
3.	Does the producer use only plant protection products included in the list of products approved for IP and authorised for use in the crop concerned?	❑/❑	
4.	Are all the documents specified in the methodology and notebook (e.g. test results, proof of purchase) present on the farm and properly stored?	❑/❑	
5.	Is the IP Notebook kept correctly and up to date?	❑/❑	
6.	Does the producer handle empty plant protection product containers and expired products in line with the provisions in force?	❑/❑	
7.	Is chemical protection of crops replaced by alternative methods wherever justified?	❑/❑	
8.	Are treatments performed with the use of plant protection products carried out exclusively by persons who hold, for the duration of treatment, a valid certificate of completion of training in the use of plant protection products or advisory on plant protection products, or integrated crop production, or another document confirming certification to apply plant protection measures?	❑/❑	

Basic requirements (100% compliance, i.e. 27 points)			
No.	**Control points**	**YES/NO**	**Comment**
9.	Is every application of a plant protection product recorded in the IP Notebook, taking into account the severity of pest infestation in accordance with the methodology and the need to carry out the treatment?	❑/❑	
10.	Were plant protection treatments carried out under appropriate conditions (optimal temperature, permissible wind speed)?	❑/❑	
11.	Is the rotation of the active substances of plant protection products used in treatments observed if possible?	❑/❑	
12.	Does the producer limit the number of treatments and the amount of crop protection products used to a necessary minimum?	❑/❑	
13.	Does the producer have measuring devices to precisely determine the quantity of the measured plant protection product?	❑/❑	
14.	Does the producer comply with the instructions on the label regarding the preparation of the working solution, the disposal of any remaining solution and the cleaning of the equipment?	❑/❑	
15.	Does the producer comply with the label's instructions regarding safety precautions for users, staff and bystanders?	❑/❑	
16.	Does the producer comply with the 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?	❑/❑	
17.	Are prevention and withdrawal periods observed?	❑/❑	
18.	Are the application rates and the maximum number of treatments during the growing season, as specified on the plant protection product label, not being exceeded (if the IP methodology imposes stricter requirements than the label, the provisions of the IP methodology shall apply)?	❑/❑	

Basic requirements (100% compliance, i.e. 27 points)			
No.	**Control points**	**YES/NO**	**Comment**
19.	Were the sprayers listed in the IP Notebook in working order and did they have valid technical certificates at the time the plant protection products were applied?	❑/❑	
20.	Does the producer carry out systematic calibration of the sprayer(s)?	❑/❑	
21.	Does the producer have a space for filling and cleaning the sprayer?	❑/❑	
22.	Are plant protection products stored in an appropriately marked closed room in such a way as to prevent contamination of the environment and access of third parties?	❑/❑	
23.	Are all plant protection products stored exclusively in their original packaging and in such a way as to prevent them from coming into contact with food, drink or animal feed?	❑/❑	
24.	Does the producer apply fertilisation on the basis of the actual nutrient requirements of the crops, determined in particular on the basis of soil or crop analyses?	❑/❑	
25.	Is each fertilisation applied recorded in the IP Notebook in terms of its form, type, date of application, quantity, location and surface?	❑/❑	
26.	Does the producer perform all the necessary agrotechnical procedures in accordance with the IP methodology?	❑/❑	
27.	Does the IP producer comply with hygiene and sanitary rules during plant production, in particular those specified in the IP methodology?	❑/❑	
	Total points		

Additional requirements for field vegetable crops (minimum compliance 50 %, i.e. 5 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	Is each field marked according to the entry in the IP Notebook?	❑/❑	
2.	Is the recommended catch crop used in	❑/❑	

	cultivation?		
3.	Are fertiliser application machines maintained in good working order?	❑/❑	
4.	Do fertiliser application machines allow for accurate dose adjustment?	❑/❑	
5.	Are fertilisers stored in a separate and specially designated room in a manner that ensures protection of the environment against contamination?	❑/❑	
6.	Does the producer protect empty PPP packaging against unauthorised access?	❑/❑	
7.	Does the producer have a properly prepared place for collecting organic waste and sorted vegetables?	❑/❑	
8.	Are there first-aid kits in the vicinity of workplaces (e.g. storage rooms, utility rooms, cold storage)?	❑/❑	
9.	Does the producer know how to proceed in the event of a spill or the scattering of plant protection products?	❑/❑	
10.	Does the producer use consultancy services?	❑/❑	
	Total points		

Recommendations (min. implementation 20 %, i.e. 2 points)			
No.	**Control points**	**YES/NO**	**Comment**
1.	Are soil maps drawn up for the holding?	❑/❑	
2.	Are non-organic fertilisers stored in a clean and dry room?	❑/❑	
3.	Has a chemical analysis of organic fertilisers been carried out in terms of nutrient content?	❑/❑	
4.	Is there an irrigation system on the farm that ensures optimal water consumption?	❑/❑	
5.	Is the water used for irrigation tested in a laboratory for microbiological and chemical contamination?	❑/❑	
6.	Does the lighting in the room where the plant protection products are stored make it possible to read the information on the packaging of the plant protection products?	❑/❑	

7.	Are there instructions on how to deal with spills or scattering of plant protection products on the farm, and are there tools to counteract such a threat?	❑/❑	
8.	Does the producer improve their knowledge at Integrated Plant Production meetings, courses or conferences?	❑/❑	
9.	Does the producer ensure, in the crop environment, conditions conducive to the survival of natural enemies of harmful organisms (other than those required in the list of mandatory activities and treatments)?	❑/❑	
Total points			

XII. FURTHER READING

Adamicki F. Czerko Z. 2002. Przechowywanie warzyw i ziemniaka. Państwowe Wydawnictwo Rolnicze i Leśne - Poznań., 324 pp.

Arya D., Prakash N.Y., Jangu R. 2023. Advances production technology of rhubarb. Chapter 22. A Textbook on advances production technology of temperate vegetable crops, 285-295.

Dobrzański A. 2015. Rabarbar bez chwastów. Warzywa 7: 42-45.

Dobrzański A. 2013. Biologiczne i agrotechniczne aspekty regulowania zachwaszczenia. pp 27 –54. In: „Współczesna inżynieria rolnicza – osiągnięcia i nowe wyzwania." Volume III (ed. R. Hołownicki, M. Kuboń). PTIR, Kraków, pp. 443.

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

Hruschka H.B. 1967. Storage and shelf life of packaged rhubarb. Marketing research Report No.771. United States Department of Agriculture. Agricultural Research Service.

Komorowska,B., Ptaszek M., Jarecka-Boncela A., Hasiów-Jaroszewska B. 2018. First Report of Arabis Mosaic Virus in Rhubarb in Poland. Plant Disease 102:1863-1863. doi: 10.1094/PDIS-02-18-0324-PDN

Lang K. 2023. Rhubarb: Harvest and storage. South Dakota State. University Extension. https://extension.sdstate.edu/rhubarb-harvest-and-storage

Matyjaszczyk E., Dobrzański A. 2015. Ochrona rabarbaru (*Rheum raponticum* L.) przed chwastami w Polsce i innych krajach. Progress In Plant Protection 55 (4): 466-471.

Rai Sub., Rai Saf., Mukhia D.J., Sikder S. 2024. Rhubarb. Published By GeNiC Books Publishers PVT. LTD. Chapter 20. Advances in potential production technology of minor vegetable crops: 234-244.

Robertson N.L., Ianson D.C. 2007. First Report of Turnip mosaic virus in Rhubarb in Alaska. Plant Disease 89: 430-430. doi: 10.1094/PD-89-0430B.

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

Commission Delegated Regulation (EU) 2023/2429 of 17 August 2023 supplementing Regulation (EU) No 1308/2013 of the European Parliament and of the Council as regards marketing standards for the fruit and vegetables sector, certain processed fruit and vegetables and the bananas sector, and repealing Commission Regulation (EC) No 1666/1999 and Commission Implementing Regulations (EU) No 543/2011 and (EU) No 1333/2011.

Szwejda J., Rogowska M. 2004. Fitofagiczna entomofauna występująca na rabarbarze. Prog. Plant Prot./Post. Ochr. Roślin, 441/:445-451.

Szwejda J. 2015. Szkodniki Roślin Warzywnych. PWN. Warsaw, pp. 251.

Soika, G. 2017. Warzywnictwo, w tym uprawa ziół metodami ekologicznymi: badania w zakresie innowacyjnych metod ochrony przed szkodnikami, chorobami i chwastami w towarowej ekologicznej produkcji warzyw i ziół. Wykorzystanie środków pochodzenia naturalnego do ograniczania szkodliwości najgroźniejszych agrofagów w ekologicznych uprawach rabarbaru, bobu i fasoli szparagowe. In: Wyniki badań w zakresie rolnictwa ekologicznego realizowanych w 2017 r. 425-439. https://www.gov.pl/web/rolnictwo/wykaz-tematow-badawczych-i-streszczenie-wynikow-badan-z-zakresu-rolnictwa-ekologicznego-realizowanych-w-2017-roku

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

Omlinson J.A., Walkey D.G.A. 2008. The isolation and identification of rhubarb viruses occurring in Britain. Annals of Applied Biology 59:415 – 427. doi: 10.1111/j.1744-7348.1967.tb04458.x

Zardzewiały M., Matlok N., Piechowiak T., Gorzelany J., Balawejder M. 2020. Ozone treatment as a process of quality improvement methods of rhubarb (*Rheum rhaponticum* L.) petioles during storage. Applied Sciences 10,8282, doi: 10.3390/app10228282