MAIN INSPECTORATE FOR PLANT HEALTH AND SEED INSPECTION

DRAFT

METHODOLOGY FOR INTEGRATED APPLE TREE CULTIVATION – *Malus domestica* L.

(eighth edition, revised and supplemented)

Approved
by virtue of Article 57(2)(2) of the Plant Protection Products Act of 8 March 2013
(consolidated text: Journal of Laws of 2024, item 630, as subsequently amended)
by
the Main Inspector for Plant Health and Seed Inspection

Warsaw, 2026

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ISBN 978-83-67039-62-8

The methodology has been updated 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’.

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PREFACE

Integrated plant production (IP) is a state-of-the-art food quality scheme involving sustainable use of technical and biological advances in plant cultivation, protection, and fertilisation that takes particular note of environmental protection and human health. A key element of IP is the application of the principles of integrated plant protection. These principles particularly prioritise the use of non-chemical methods, which should be supplemented by pesticide use when predicted economic losses caused by harmful organisms will be greater than the cost of treatments.

Among other things, application of IP is a guarantee of production of high-quality food, not exceeding permissible residues of harmful substances, less expenditure on production (application of fertilisers 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.

Above all, the IP certificate may be granted if, among other things, production is carried out in accordance with this methodology approved by the Main Inspector for Plant Health and Seed Inspection.

The Methodology of Integrated Apple Tree Production covers all aspects of apple tree cultivation, protection and fertilisation, from soil preparation and tree planting, through agricultural methods and pest management, to harvesting and storing apples. The methodology also takes into account hygiene and health rules to be complied with during harvest and preparation for the sale of crops produced under integrated plant production and general principles for the issue of integrated plant production certification.

This methodology was developed based on the results of proprietary research and the latest data from the literature, in compliance with the guidelines of the International Organisation for Biological and Integrated Control (IOBC), and 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 State Plant Health and Seed Inspection Service at https://www.gov.pl/web/piorin/zasady-ip.

I. SOIL PREPARATION AND ORCHARD ESTABLISHMENT

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1. Site selection

A site for a new orchard should be selected in such a way that the plantation ensures a regular high-quality fruit crop, and thus economic success with minimal use of chemicals. A site with favourable microclimate conditions should be selected for orchards, i.e. trees should not be planted in frost basins or on wetlands and on excessively sandy and dry soil. A small hill sheltered from north-western and western winds, where trees will not freeze in hard winters and avoid frost damage in spring, is a perfect site for an apple orchard. Hollows and river valleys are not the right place for an orchard due to frost pockets (Mika 2010).

Apple trees grow well on soils of average fertility, which are soils of grade 3 and 4 quality. Loess soils and light clay soils are very good for dwarf and semi-dwarf trees. Apple trees can also be grown on loam soils. Irrigation is necessary on sandy soils. The groundwater level should not be higher than approximately 100 cm for dwarf apple trees and approximately 140 cm for semi-dwarf apple trees. The soil pH for apple trees should be slightly acidic (6.0 to 6.7).

Apple orchards should not be planted near industrial plants that cause environmental pollution. Blooms exposed to acid rain are less likely to form fruit.

2. Forecrops and crop rotation

Apple trees grow best when planted on land not previously used for fruit growing. In spring, a year before planting the trees, seeds of plants for green manure should be sown and ploughed in when they are fully blooming. The most valuable green manure is obtained from a mixture of legumes: lupine, field pea, vetch, broad bean, with the addition of cereals: phacelia, sunflower and maize. These plants form a large green mass, clearing the soil of weeds. They are a source of humus and improve the soil structure. Fruit trees should not be planted after perennial Fabaceae species because they may be at risk of certain diseases and pests, for example grubs, or wireworms after clover or alfalfa. Between 150 and 200 kg of leguminous plant seeds must be sown and at least 50 kg of pure-ingredient nitrogen must be applied per hectare.

Mustard is a valuable and cheap green manure. Just sow 30 kg of seeds per ha. Mustard is sown as early as possible in the spring, adding 100 kg of urea before sowing or strengthening the plants with 100 kg of ammonium nitrate after their emergence. Mustard flowers early, at the end of June or the beginning of July. Mustard is shredded with a green fodder harvester or orchard mower, and is immediately, shallowly ploughed in, and then sown again, fed with fertilisers as in spring. The second mustard crop is to be ploughed down in September or October. In this way, it is possible to incorporate large amounts of organic matter into the soil. Mustard ploughed into the soil reduces harmful nematodes. In addition, there are no mice or voles in fields where mustard has grown. Mustard is a phytosanitary plant, so it is always recommended as a forecrop where it is necessary to plant one orchard in the place of another. Plants grow poorly if the same crop is grown repeatedly on the same piece of land which is referred to as soil fatigue. In horticulture, soil exhaustion results in replant disease. It is manifested by the weakening or complete inhibition of the growth of the overground part and roots of saplings planted immediately after the removal of a previous orchard. Apple trees are very susceptible to replant disease.

A good way to avoid soil exhaustion is to activate its biological potential by incorporating a large amount of organic matter into it. The simplest solution is to use a high dose of manure (40-50 tonnes per hectare), peat or compost and perform stubble ploughing (25-30 cm). Manure can be replaced with green fertiliser. In order to reduce the presence of certain nematodes in the soil, marigolds should be grown. In spring, 5 to 10 kg/ha of seeds of this annual plant are sown. In autumn, plants should be shredded and ploughed in. To reduce the number of grubs in the soil, buckwheat can be sown. After it grows, buckwheat is crushed and ploughed back into ground.

3. Orchard surroundings and agricultural techniques of pest control

In areas exposed to strong winds, plants should be planted for protection on the west and north-western side. It is easy to set up a cover by planting one or two rows of quickly growing trees along the border of an orchard. Alders, planted densely at intervals of 1-2 m, which quickly form a dense yet slender line, are suitable for this purpose. Also linden is highly indicated for this purpose as melliferous trees. Strong growing trees such as poplars, acacias and ashes should be avoided, as they soon compete with apple trees in the orchard. Hawthorn, rowan and serviceberry trees should not be planted because of the possibility of a fire blight. It is recommended to grow trees and shrubs producing juicy food for birds such as: wild cherries, mulberry, fruit roses, etc.

New fruit tree plots are usually established in orchard zones where old orchards have been previously grubbed up, and where old trees and shrubs usually grow along borders, fences, roads and around wasteland. When replanting an orchard, the trees and shrubs around or outside the orchard must be kept. Trees and bushes between orchards and within an orchard provide a refuge for beneficial insects and birds. Only a naturally diverse environment can ensure biological balance and reduce the use of chemical plant protection products. When fencing off orchards, care should also be taken to provide small predatory animals such as martens, weasels, polecats and ermines with refuge, as they help to reduce the population of field mice, voles and water voles. Scrub and stone rubble, which serve as a refuge for predatory animals, must be kept by the orchard fence. Nesting boxes should be hung for birds in the orchard, and poles with crossbars should be set up for birds of prey. It shall create favourable conditions for the reproduction of beneficial organisms. To reduce the number of grubs and wireworms in the soil, the soil should be cultivated with a disc harrow.

4. Density of planting trees

The greatest progress in horticulture is made due to dwarfing rootstocks. Thanks to them trees can be planted densely, the result of which are high fruit yields shortly after the orchard is started. The best results can be achieved by planting between 1 500 and 3 000 dwarf apple trees per hectare or between 1 000 and 1 500 semi-dwarf trees. A density higher than 3 000 trees per hectare significantly increases the costs of starting an orchard. It may also be one reason for the deterioration of fruit quality, and makes it difficult to protect trees from diseases and pests. Excessive density causes lack of sunlight, and thus fruit do not grow to the required size; they lack the appropriate blush, have less sugar and dry matter, taste worse and are less storable. If a lot of pruning is done to prevent excessive tree density, then fruit is higher in nitrogen, and lower in calcium. Apples from such an orchard do not store well. In the popular row-planting system, dwarf apple trees are planted at a spacing of 3.5 m between rows and of 1.0-2.0 m in the row, while for semi-dwarf apple trees the spacing between rows should be 4.0 m and 1.5-2.5 m in the row.

The recommended planting distances for trees should not always be taken literally. The local soil and climate conditions must be taken into account. Strong-growing varieties should not be planted too densely, especially in the foothills belt, where clay soils and abundant rainfall stimulate growth. It is also worth remembering that trees planted in the place of an old grubbed up orchard always grow weaker than they would in a new area.

Apple trees can be planted in autumn or early spring. Autumn planting helps trees to take root and to grow intensively in spring. However, autumn planting of apple tree varieties that are not very frost-resistant and grafted onto frost-sensitive rootstocks should be avoided.

If it is not certain whether the fence will be an effective method of protection against hares, rabbits, roe deer, etc. animal repellents should be applied to trees after autumn planting. Another solution is rigid PVC covers, paper, or straw.

5. Variety as a facilitator of integrated production

The choice of varieties is an important part in integrated apple tree production because of the genetically determined susceptibility/resistance of varieties to various diseases. The choice of variety determines the costs associated with protection against diseases, and determines successful crops. Several factors have to be taken into account when deciding which variety to choose. In addition to susceptibility to disease, it is important to adapt a variety to local soil and climate conditions. A good choice in this respect maintains the health of the trees throughout the growing period, and indirectly affects their overall health. If varieties are selected according to the conditions in which an orchard is to grow, this contributes to good crops. Factors that also should be taken into account when selecting a variety include: the market value of the variety, the quality of fruit and the shelf life during storage and marketing. The Apple Varieties Register can be found at: https://www.coboru.gov.pl/pl/kr/kr_odm?kodgatunku=JADO.

Rootstocks

Rootstocks should be selected to match the variety size, and the soil on which an orchard will grow. When selecting a rootstock, attention should be paid to the growth strength that influences the premium variety, frost resistance and susceptibility to diseases and pests. The choice of good rootstock ensures the abundance of flowering and their longevity, as well as high-quality yields. The Apple Varieties Rootstock Register can be found at: https://www.coboru.gov.pl/pl/kr/kr_odm?kodgatunku=JADP.

Pollinators for apple trees

Apple trees are cross pollinators and they need pollinators to bear fruit. Although some varieties of apple trees are self-fertile, their fruit do not meet high-quality criteria, which means that they can only be considered as industrial apples. The period of flowering should be the main factor when selecting a pollinator. A single plot should contain varieties with a similar flowering period. The ratio between the pollinating variety and the main variety is also important. On the basis of experiments, it was found that good pollination conditions exist when the pollinator is 10-15 % of the variety being pollinated. This means that there is one pollinator tree for eight trees of the pollinated variety. An accurate choice of pollinators and their arrangement on the plot should provide ideal conditions for pollinating, as well as a regular and abundant yield. This inhibits the growth of trees and, consequently, indirectly facilitates the implementation of protection treatments.

In apple orchards, ornamental apple trees can be used as pollinators. The advantages of these varieties are: very early fruiting, abundance of flowering, high pollen production and the possibility of strong pruning. The latter feature means that they do not take up much space. In this type of variety, flower buds are set mainly on 1-2-year-old shoots.

II. FERTILISATION AND LIMING

Dr hab. Paweł Wójcik, prof. IO

Fertilisation of orchard plants is based on soil and leaf analysis and on visual evaluation of the plant. Soil analysis is obligatory in integrated fruit production.

1. Soil analysis and its significance in fertilisation strategy

Soil sampling and preparation for analysis

Soil samples are collected separately from sites of different topographies (upper, middle and lower elevation parts) and different fertilisation histories.

In an existing orchard, soil samples are collected only from the herbicide/mechanical strips along tree rows. Samples are collected within these strips, halfway between the tree row line and the edge of the turf area. If trees are irrigated with a drip system, samples should be taken about 20 cm from the emitter.

Soil samples are taken from two levels, i.e. from a layer of 0-20 cm and 21-40 cm, both before planting the orchard and in the course of operating it. Before setting up an orchard, soil samples are best taken one year before planting trees. In an existing orchard, soil samples are collected once every three to four years; on light soils – once every three years, and on heavier soils – once every four years. The collected soil samples should be dried in the shade, and sent to an agrochemical laboratory.

Basic soil analysis must comprise the soil pH value, the organic matter content and the available phosphorus (P), potassium (K) and magnesium (Mg). The determination of the particle size composition of the soil is also justified.

Fertilising with P, K and Mg on the basis of soil analysis

Fertilisation with the above-mentioned nutrients is based on the comparison of soil analysis results to the so-called limit values of P, K and Mg content (Tables 1-3). Following the assignment of a particular mineral’s content in the soil to a corresponding abundance class, a decision is made whether fertilising with that mineral is justified and, if so, regarding its dose.

Fertilising with nitrogen (N) on the basis of soil analysis

N fertiliser needs of apple orchards can be estimated on the basis of soil organic matter content (Table 4). The given N doses should be treated as indicative and should always be verified with the growth of trees and/or the N content of the leaves (Table 8).

Liming based on soil analysis

Evaluation of liming needs and the calcium dose depend on soil pH and soil texture, as well as the period of liming (Tables 5-7).

2. Chemical analysis of leaves and its role in the fertilisation strategy

Sampling of leaves and preparation for analysis

Leaves (with petioles) are taken only from trees that bear fruit, from the middle part of the annual shoots and crown, at a height of 1.5-2.0 m. Leaf samples are collected from 20-25 trees. 5-7 leaves are collected from each tree. Apple tree leaf samples are collected 2-4 weeks after shoots stop growing, i.e. between 15 July and 15 August. Considering the high variability of plant nutrition between growing seasons, leaves are best sampled in two consecutive years in 4-year-long cycles.

Collected leaves are placed in paper bags. The leaves should be dried as soon as possible (preferably on the same day) at 60-70 °C. If it is not possible to dry them on the spot, the leaf sample can be kept for 1-2 days in a refrigerator, and then delivered to an agrochemical laboratory.

Fertilisation based on leaf analysis

Using the results of leaf analysis for orchard fertilisation involves comparing the amount of the nutrient in the sample with the so-called limit numbers (Table 8).

3. Fertilisation before an orchard is started

Organic fertilisation

The use of natural and organic fertilisers/soil-enhancing agents before planting trees improves their growth and yield. Livestock manure is the most valuable natural fertiliser. Its annual dose may not exceed 170 kg N per ha. Do not use manure on soils that are covered with standing water, snow, or which are frozen to a depth of 30 cm. The time for using manure depends on the period of setting up the orchard and the agronomic category of the soil. On light soils, manure must not be used in autumn. When trees are planted in autumn, manure should be applied under the forecrop. When establishing an orchard in spring on a light soil, well-fermented manure is best used immediately before planting trees.

So-called green manure, i.e. crops that are supposed to be ploughed into the soil, constitute an alternative to manure. The fertilising value of these plants depends on the amount of biomass produced and its mineral content. Detailed information on the application of green manure before starting an orchard can be found in Chapter I, Section 2. (‘Forecrops and crop rotation’).

Mineral fertilisation and liming

Before planting saplings, it may be necessary to use fertilisers or soil improvers containing P and/or K. The need for P and K fertilisation, and the required application rates, are determined by the concentration of these elements in the soil (Tables 1 and 2).

Phosphorus fertilisers can be applied both under the forecrop and immediately before planting trees. It is recommended that potassium-based fertilisers be used immediately before planting. Applying K fertilisers under forecrops is only justified if high doses of K are used in the form of potassium chloride (potassium salt). Phosphate and potassium fertilisers must be mixed with the soil at least 20 cm deep.

Liming requirements depend on the current soil pH and its agronomic category (Tables 5, 6). Liming is best carried out one year before establishing an orchard. If it is necessary to both increase the pH of the soil and the Mg content, liming materials containing Mg should be used in a dose based on the need for lime.

It is recommended to use lime in carbonate form on light soils, and in oxide form (quicklime) or hydroxide form (quenched lime) on medium and heavy soils.

4. Fertilisation in the first two years of running an orchard

If the fertiliser was applied correctly before the trees were planted, then during the first two years of orchard establishment, mineral fertilisation is limited to nitrogen only.

The recommended N doses are 5-20 g per m^2 of the fertilised area (Table 4) depending on the content of organic matter in the soil. These doses apply to orchards in which mechanical fallow is carried out over the entire area or in strips along the tree rows. Where turf is kept on the entire area of an orchard or when a lot of weeds exist around saplings, the doses of N should be increased by about 50%. N doses should also be increased (by 30 %-50 %) when organic mulches with a high carbon/nitrogen ratio (e.g. straw, bark, branch cuttings) are laid in the tree rows.

In the first year of orchard establishment, nitrogen fertiliser is applied twice; the first dose, accounting for about 30 % of the fertiliser needs, is applied during the swelling and breaking of buds, and the remaining dose (70 %) at the end of June. In the second year of tree growth, it is also necessary to divide the annual N dose into two parts. The first dose of N, amounting to about 50–70 % of fertilisation needs, is applied early in spring, and the rest (30–50 %) is applied at the end of June.

In the first two years after planting trees, nitrogen fertilisers are applied around their trunks within a radius of around 1.5 times the crown’s reach. With dense tree planting, nitrogen fertilisers are spread in strips along tree rows.

5. Fertilisation and liming in a fruit-bearing orchard

Nitrogen fertilisation

Depending on the soil’s organic matter content (Table 4) and N level in leaves (Table 8), the optimum N doses for apple orchards vary between 20 and 80 kg per hectare. These doses refer to orchards where herbicide or mechanical fallow is maintained along tree rows.

In the fruiting orchard, nitrogen fertilisers should be spread in strips along rows of trees to the surface of the herbicide/mechanical fallow.

Fertilisation with phosphorus

The P fertiliser is applied if the results of the soil/leaf analysis show that the P content in soil/leaves is too low (Table 1, 8) or if there are signs of deficiency of this nutrient in the plant. In the above cases, phosphorus fertilisers are applied by the foliar method or are spread on the soil surface along tree rows, and then mixed with the soil to a depth of about 5 cm.

Fertilisation with potassium

If the soil was properly prepared before establishing an orchard, potassium fertilisers are usually applied from the third year of cultivating an orchard. The need for K fertiliser and its dose is determined by the K content in the soil and leaves (Table 2, 8).

Potassium fertilisers are applied in the spring or in the autumn. Spring application is recommended for light soils, and autumn application for medium and heavy soils. Autumn fertilisation with K is also justified when using potassium salt.

Fertilisation with magnesium

The use of magnesium fertilisers is justified 3-4 years after the orchard was started, provided that the Mg content of the soil was appropriate at the time of planting trees. The need for Mg fertilisation is determined by soil analysis (Table 3), Mg content in leaves (Table 8) and appearance of trees.

If it is necessary to both increase the Mg level in soil and the pH in an orchard, magnesium lime should be used. Doses of lime enriched with Mg, and the time and method of its application depend on the need for liming.

Micronutrient fertilisation

Chemical analysis of leaves (Table 8) and/or visual evaluation of the leaves and fruits determine the desirability of supplying apples with micronutrients. If the chemical analysis of the leaves reveals insufficient micronutrient content, then fertilisation with these components is justified.

Fertigation

It is a method of fertilisation consisting in feeding plants with components through an irrigation system. With this fertilisation system, only fertilisers that are highly soluble in water are used. Doses of substances used for fertigation are several times lower than the doses recommended in the conventional use of fertilisers. The fertigation of apple trees is carried out from the first days of May to mid-August, every five to seven days. The best production effects are obtained with the combined use of fertigation with traditional fertilisation (however, at reduced doses of the elements).

Calcium (Ca) spraying and physiological disorders of apples

Apples low in Ca are prone to cracking, sunburn, and some physiological disorders (e.g. bitter pit, watercore, lenticel rot, internal browning, breakdown) as well as fungi infections.

Ca deficiency in apples results from the fact that this nutrient is transported mainly to the leaves. Therefore, it is most often necessary to provide fruits with Ca by foliar application.

In apple orchards, three to seven Ca sprays should be applied. Apples of the ‘Champion’, ‘Jonagold’, ‘Cortland’, ‘Rubin’, ‘Honeycrisp’ varieties require more Ca sprays in the given range. Young plantings are sprayed more intensively with calcium solutions. Trees are also sprayed when crops are poor. More Ca sprays are also recommended under water stress (water scarcity) during the summer and when fruit is stored for a long time, especially in cold storage.

It is advisable to apply the first Ca spray as early as mid-June, when the fruitlets are the size of a walnut, to reduce physiological disorders, the symptoms of which can be seen deep in the flesh of the fruit (e.g. internal browning, watercore). Subsequent sprays are applied at intervals of approximately 14 days.

Liming

If, at the time of planting, the soil pH was appropriate for growing apple trees (6.0-6.7), liming should be carried out after another three to four years. The size of the lime dose depends on the soil’s agronomic category and current soil pH (Table 7). During a periodic lime application of an orchard, plum trees are subject to fluctuations of soil pH, which may weaken their growth and/or yield. For this reason, it is better to maintain the optimum soil pH throughout the life of the orchard. In order to stabilise the soil acidity, approximately 300 kg of CaO per ha should be used annually (after reaching an optimum soil pH level).

Liming should be carried out early in the spring or late in the autumn. When liming in spring, fertilisers are applied when the surface of the soil is thawed and trees have not formed leaves. Autumn lime application is best done between the end of October and the first half of November.

Table 1. Soil fertilisation with phosphorus (P) before establishment of and during orchard depending on the content of assimilable P in the soil[*] (Kłossowski, 1972 modified by Wójcik, 2021)

P abundance of the humus layer		
low	optimal	high
P content [mg kg^{-1}]		
<40	40-80	>80
Phosphorus fertilisation prior to establishing the orchard [kg P_2O_5 ha^{-1}][a]		
100-150[b]	50-100[b]	0-50[b]
Fertilisation with phosphorus in an orchard [g P_2O_5 m^{-2}][c]		
10-15	0	0

[*] Content of assimilable P in soil determined by the Egner-Riehm method.

[a] Phosphorus dose applied onto the fertilised surface.

[b] Apply decreased or increased phosphorus doses by 20 % when its content in the layer below the humus level is > 40 mg P kg^{-1} and < 20 mg P kg^{-1}, respectively.

[c] Apply orthophosphate-based phosphate fertilisers along the rows of trees in orchards that are more than 3 years old, working them into the soil to a depth of approximately 5 cm. Fertilisers containing polyphosphates should be used in young orchards (up to 3 years old) without the need to mix them into the soil.

Table 2. Soil fertilisation with potassium (K) prior to establishing the orchard and while maintaining it, depending on the bioavailability of K in the soil[*] and the granulometric composition (Kłossowski, 1972 modified by Wójcik, 2021)

Share of soil particles with a size of < 0.02 mm [%] in the earth part	Abundance of K in the humus layer		
	low	optimal	high
<20	K content ($mg\ kg^{-1}$)		
	<50	50-80	> 80
	Potassium fertilisation prior to orchard establishment [kg K_2O ha^{-1}][a]		
	150-200 [b]	100-150[b]	-
	Potassium fertilisation in orchard [g K_2O m^{-2}]		
	8-10 [b]	5-8[b]	-
20-35	K content ($mg\ kg^{-1}$)		
	< 80	80-130	>130
	Potassium fertilisation prior to orchard establishment [kg K_2O ha^{-1}][a]		
	200-250 [c]	150-200 [c]	-
	Potassium fertilisation in orchard [g K_2O m^{-2}]		
	10-12 [c]	8-10 [c]	-
>35	K content ($mg\ kg^{-1}$)		
	< 130	130-210	> 210
	Potassium fertilisation prior to orchard establishment [kg K_2O ha^{-1}][a]		
	250-300[d]	200-250[d]	-
	Potassium fertilisation in orchard [g K_2O m^{-2}]		
	12-16[d]	10-12[d]	-

[*] Assimilation of K in soil determined by the Egner-Riehm method.

[a] Potassium dose applied onto the fertilised surface.

[b] K doses reduced or increased by 20 % should be used when its content in the layer directly below the humus level is >50 mg K kg^{-1} and <30 mg K kg^{-1}, respectively.

[c] K doses reduced or increased by 20 % should be used when its content in the layer directly below the humus level is >80 mg K kg^{-1} and <50 mg K kg^{-1}, respectively.

[d] K doses reduced or increased by 20 % should be used when its content in the layer directly below the humus level is >80 mg K kg^{-1} and <30 mg K kg^{-1}, respectively.

Table 3. Soil fertilisation with magnesium (Mg) before establishment of and during operation of the orchard depending on the assimilability of Mg in the soil[*] and granulometric composition (Kłossowski, 1972 modified by Wójcik, 2021)

Soil particle of <0.02 mm content (%) in the earth	Abundance of Mg in the humus layer		
	low	optimal	high

fraction			
<20	Mg content (mg kg^{-1})		
	<30	30-50	>50
	Magnesium fertilisation prior to plantation establishment [kg MgO ha^{-1}][a,b]		
	80-100[c]	60-80[c]	-
	Magnesium fertilisation in an orchard [g MgO m^{-2}]		
	8-10[c]	6-8[c]	-
≥20	Mg content (mg kg^{-1})		
	<50	50-70	>70
	Magnesium fertilisation prior to orchard establishment [kg MgO ha^{-1}][a,b]		
	100-120[d]	80-100[d]	-
	Magnesium fertilisation in orchard [g MgO m^{-2}]		
	10-12[d]	8-10[d]	-

[*] Mg assimilability in soil determined by the Schachtschabel method.

[a] Magnesium dose applied to the fertilised area.

[b] Where the reaction of the humus layer is below the optimal value for a given plant species, magnesium lime should be used at a dose appropriate for the liming needs.

[c] Magnesium doses reduced or increased by 20 % shall be applied when its content in the layer immediately below the humus level is >50 mg of Mg kg^{-1} DM and <35 mg Mg kg^{-1}DM, respectively.

[d] Magnesium doses reduced or increased by 20 % shall be applied when its content in the layer immediately below the humus level is >70 mg of Mg kg^{-1} DM and <50 mg Mg kg^{-1}DM, respectively.

Table 4. Indicative nitrogen (N) doses for apple orchards based on soil organic matter content (Wójcik, 2009)

Orchard age	Organic matter content (%)		
	0.5-1.5	1.6-2.5	2.6-3.5
	Dose of Nitrogen		
First two years	15-20*	10-15*	5-10*
Subsequent years	60-80**	40-60**	20-40**

* N dose in g/m^2 of fertilised area

** N dose in kg/ha of fertilised area

Table 5. Assessment of liming needs for mineral soils depending on soil agronomic category and pH

Liming requirements	pH			
	Agronomic category of the soil			
	Very light	Light	Medium	Heavy
Necessary	< 4.0	< 4.5	< 5.0	< 5.5
Needed	4.0-4.5	4.5-5.0	5.0-5.5	5.5-6.0
Recommended	4.6-5.0	5.1-5.5	5.6-6.0	6.1-6.5
Limited	5.1-5.5	5.6-6.0	6.1-6.5	6.6-7.0

unnecessary	> 5.5	> 6.0	> 6.5	> 7.0

Table 6. Recommended lime doses depending on soil agronomic class and soil pH value*

Liming requirements	CaO dose (t/ha)			
	Agronomic category of the soil			
	Very light	Light	Medium	Heavy
Necessary	3.0	3.5	4.5	6.0
Needed	2.0	2.5	3.0	3.0
Recommended	1.0	1.5	1.7	2.0
Limited	-	-	1.0	1.0

* Doses given in the Table should be used only before setting up an orchard, preferably for forecrop.

Table 7. Single doses of lime used in the orchard (Kłossowski, 1972, modified by Wójcik, 2021)

Soil pH	Agronomic category of the soil		
	Light	Medium	Heavy
	Dose [kg CaO 100 m^{-2}][a,b]		
<4.5	17	20	30
4.5-5.5	10	15	20
5.6-6.0	5	8	15
6.1-6.5	-	5	10
6.6-7.0	-	-	5

[a] Recommended lime doses on a 3–4 year cycle.

[b] Use lime only on the herbicide/mechanical fallow strips along the rows of plants.

Table 8. Limit numbers of ingredients in apple leaves[a] (according to Kłossowski 1972, supplemented and modified by Sadowski et al. 1990 and Wójcik 2021) and recommended doses of ingredients used on soil in the fruiting orchard

Ingredient/dose in fertilisation *	Content range of ingredient			
	deficit	low	optimal	high
N (%)	**< 1.80**	**1.80-2.09**	**2.10-2.40**	**> 2.40**
Dose of N (kg ha^{-1})	*100-120*	*80-100*	*20-80*	*0*
P (%)	**< 0.11**	**0.11-0.14**	**0.15-0.26**	**>0.26**
Dose of P_2O_5 (kg ha^{-1})	*150*	*100*	*0*	*0*
K (%)	**<0.70**	**0.70-0.99**	**1.00-1.50**	**>1.50**
Dose of K_2O (kg ha^{-1})	*120-140*	*80-120*	*50-80*	*0*
Mg (%)	**<0.18**	**0.18-0.21**	**0.22-0.32**	**>0.32**
Dose of MgO (kg/ha^{-1})	*100-120*	*60-100*	*0*	*0*
S (%)**	**-**	**0.004-0.009**	**0.01-0.2**	**-**
B (mg kg^{-1})	**<18**	**18-24**	**25-45**	**>45**
Dose of B (kg ha^{-1})	*3-4*	*1-2*	*0*	*0*
Mn (mg kg^{-1})	**<20**	**20-40**	**41-100**	**>100**

Dose Mn (kg/ha^{-1})	*15-20****	*10-14****	*0*	*0*
Zn (mg kg^{-1}) *Dose of Zn (kg/ha^{-1})*	**<10** *8-11****	**10-14** *6-7****	**15-60** *0*	**-**
Fe (mg kg^{-1}) *Dose of Fe (kg ha^{-1})*	**<21** *30-40****	**21-79** *20-29****	**80-250** *0*	**-**
Cu (mg kg^{-1}) *Dose of Cu (kg/ha^{-1})*	**<3** *6-7****	**3-4** *5****	**5-12** *0*	**-**
Mo (mg kg^{-1}) *Dose of Mo (kg ha^{-1})*	**-**	**0.04-0.09** *0.03-0.06*	**0.1-0.3** *0*	**-**

[a] Leaves with petioles sampled between 15 July-15 August, from the middle part of one-year's tree growth.

* Doses of ingredients per fertilised area.

** Potassium sulphate should be used according to fertilising needs for potassium

*** For limed or carbonated soils, chelate fertilisation or spraying with Fe, Mn, Zn and/or Cu should be applied.

III. SOIL CARE AND WEED CONTROL

Dr hab. Jerzy Lisek, prof. IO

1. A comprehensive approach to soil care and regulation of weeds

Soil care consists in measures that maintain it in a state that enables planting of trees and improves the conditions for their growth in the orchard. The main goals are improvement of soil structure, fertility, and aeration, improvement of water infiltration into the deeper layers, ensuring that machines can pass, and the removal of weeds. Uncontrolled growth of weed limits the growth and yield of crop plants. Weeds compete with trees for water, nutrients, and light; they have adverse chemical effects (allelopathy); they worsen phytosanitary conditions, which favors the development of fungal diseases and pests (rodents, spider mites, aphids, wireworms, dock sawflies), and they increase tree damage caused by spring frosts. On the other hand, weeds, as the most important component of what is known as synanthropic flora (flora associated with human activity), perform useful functions, referred to as ecosystem (environmental) services – they form the basis of biological diversity and help to reduce soil erosion, compaction and salinisation, as well as the leaching of nutrients. They participate in the nutrient cycle and in the sequestration (binding) of atmospheric carbon dioxide and its accumulation in organic form in the soil. It is particularly important to maintain the synanthropic flora in the autumn-winter period, when it serves as cover vegetation. The vegetation growing on the soil in an orchard whilst the trees are dormant does not meet the definition of weeds, as its presence is desirable and does not result in any economic losses. Weed control includes a set of activities that keep their number at a sufficiently low level, which allows for good development and yielding of the crops. The growth of weeds between April and August brings about the greatest threat. Actions taken should be appropriate to the risk posed and implemented in the form of a preplanned, coherent programme. While establishing an orchard with integrated production and during its operation, chemical methods of weed control (use of herbicides) and non-chemical methods — mechanical treatments (growing soil, mowing unnecessary vegetation), maintenance of cover plants, littering, and rarely used physical methods (e.g. weed burning with a propane burner and treatment with hot water).

Hot-water weed control machines consist of three essential components, common to all models: a water heating system (burner + boiler), a pump to ensure water flow, and a control system for the operation of the entire machine. They heat water continuously to a temperature of 99.5°C by burning diesel fuel (heating oil) or gas (LPG). Both the implementation of propane burners and of hot-water spreading equipment are associated with the need to purchase additional, often expensive devices and require significant consumption of fossil fuels. The first step is to use alternative methods to herbicides. Herbicide spraying is recommended when alternative methods prove to be ineffective, difficult to implement or too expensive. Individual soil management methods are combined in various ways and applied concurrently (turf in inter-rows and weeding or mulches under tree canopies), within a rotation (alternating use of different methods, most often soil cultivation and post-emergence herbicide spraying), and as a mutual supplementation of methods (weeding or post-emergence herbicide spraying to destroy perennial weeds growing through the mulch layer). Preventive measures are an important element of protection, including combating weeds before the establishment of orchards, before their forming of seeds, and in the immediate vicinity of the orchard, if their seeds are transferred with the wind. Weed communities are dominated by 30–40 species, but several hundred more may be present in varying abundance, depending on habitat conditions and the field’s history. Based on developmental biology, weeds are classified as annuals, biennials and perennials (permanent). Orchards are home to both segetal species (which grow as weeds in arable fields) and ruderal species (which grow in areas not used for agriculture). Effective control of weed infestation requires proper identification of weeds, knowledge of their biology, and the correct choice of control method. When making a choice, we consider costs, the farm’s organisational capabilities, effectiveness, environmental impact, apple trees and crop quality, including consumer safety when herbicides are used.

2. Chemical weed control methods

Before establishing an orchard, systemic foliar herbicides can be used to control perennial (permanent) weeds. In plantations older than three years, the use of soil herbicides is prohibited. Herbicides are to be used only under tree crowns, in herbicide strips whose area should not exceed 50 % of the total planting area. This means that with a typical tree spacing, the maximum width of herbicide belts amounts to 1.80 m and is recommended to be as small as possible. Foliar herbicides are most often applied in three basic periods: at the turn of April and May, in June and in July, and in the case of agents acting well at low temperatures, in autumn, in November. If the date of use (e.g. until blooming or after harvesting the crop) or a possible waiting period expressed in days is not indicated in the label, the product should be used no later than one month before harvesting fruit. With regular use of herbicides, care should be taken to rotate (alternate) agents with different mechanisms of action, which is becoming more and more difficult. It must be taken into account that the number of active substances with herbicidal action recommended for orchards in the European Union shall continue to be reduced. Therefore, it is suggested that solutions alternatives to herbicides be implemented. The scope and method of using chemical herbicides, including the maximum number of treatments in the season, should be consistent with their labels. Herbicide spraying should take place under conditions and in a manner that shall help to achieve maximum potential efficacy. The optimal spraying effect is achieved by the correct selection of: the type of agent and adjuvant (booster), if one is recommended, doses, timing of treatment – taking into account the weed development stage and weather conditions, the volume of spray liquid and the spraying technique.

Plant protection products should be used in accordance with the recommendations given on the label and in a way that does not endanger human health, animals or the environment.

The list of protection products authorised for integrated production is available on the website of the Institute of Horticulture – NRI: https://www.inhort.pl/serwis-ochrony-roslin/ochrona-roslin-rosliny-sadownicze/rosliny-sadownicze-wykaz-srodkow/and on the Pest Alerting Platform at https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.html.

Useful information on plant protection is also published in the online HortiOchrona Decision Support System for horticultural plant protection (hortiochrona.inhort.pl).

3. Mechanical methods of weed control

Mechanical weed control is usually based on systematic cultivation of the soil and is mainly carried out in the inter-rows of a young orchard. The surface maintained in this way is called bare or mechanical fallow. Soil cultivation during plant vegetation is carried out at different frequencies (from 10 days to 4 weeks), using rotary cultivators, cultivators, harrows or cultivation units. Active rotovators, with knives installed on a rotating shaft, are very effective tools, but they quickly damage the structure of the soil, which leads to a decrease in organic matter content and fertility. Active rotovators have been increasingly substituted by self-propelled rotovators. Passive tools are also preferred, with working elements such as teeth, cultivator points and coulters (cultivator type), often combined with an open cage roller or disc harrows. During the growing season, soil cultivation is shallow, to a depth of a few centimetres. Cultivations are carried out after a mass emergence of weeds, abundant rainfall and after the formation of the soil crust. The number of treatments performed in spring and summer should be limited to 4-6 treatments during the season to reduce soil degradation and erosion. The last one is recommended to be performed no later than in August. In the inter-rows of young orchards, black fallow can be maintained throughout the season or only from spring to late June and July. No later than 10 July, cover crop seeds are sown, preferably in a mix. The mixture should consist of at least 3-4 crop species, including leguminosae (legumes), e.g. serradella, broad beans, sown together with sunflower, mustard, buckwheat or phacelia. Cover plants are cut and harvested only the following year.

In orchards, there is the possibility of mechanised soil cultivation under the tree crowns using automatic rotary cultivators or weeders with undercutting knives placed on lateral, tilting working sections or self-propelled rotary cultivators with a large finger star (finger weeder) which destroys weeds in the tree line, or orchard rotary cultivators working in strips.

Mechanical cultivation may form part of a comprehensive soil maintenance technology using the ‘sandwich method’. When using this system, a non-cultivated strip of herbaceous vegetation of 30-50 cm wide is left in the middle of a row of trees. This strip may optionally be sown with cover plants, mown, periodically sprayed with herbicides, burnt with a propane burner or treated with hot water. On either side of the row of shrubs, there is a strip of shallowly cultivated soil 60–90 cm wide. Cultivation should be carried out to a depth of 5–10 cm once the weeds have reached a height of around 10 cm, 5–6 times between April and August, preferably using a self-propelled tiller, a spring-tine harrow or a disc harrow mounted on a side-mounted boom. Turf is maintained between inter-rows. Mowing unnecessary vegetation is especially important in the second half of summer to limit seed spread. For work in rows of trees, grass trimmers (cutters) are intended, and their cutting elements can be blades, strings, or scissors. Shallow mechanical cultivation and mowing do not effectively combat deep-rooting and creeping perennial weeds, like couch grass.

4. Ground cover plants

Cover crops, in the form of perennial meadow grasses, most often – red fescue (both clump and creeping forms), smooth meadow grass and perennial ryegrass (English ryegrass) – are the optimum way to maintain inter-rows in the orchard. Turf may consist of mixtures of listed species or mixtures of ecotypes (varieties) within one species, whether or not listed here, suitable for local conditions. Grass is usually planted three years after trees have been planted, and mowed at a height of 15 cm, usually 4-8 times a season. The frequency of mowing depends on the composition of the turf, weather conditions and the type of mowers – rotary, drum or flail-type. The last two types allow for a low and thus less frequent mowing. The so-called natural turfing of the inter-rows is also allowed, especially if grasses start to grow in them, e.g. annual meadow grass and slowly growing dicotyledon weeds, e.g. geraniums, daisies, speedwells, hawkweed, hawksbeard, common yarrows. The presence of dandelion is not desirable due to its expansion throughout the orchard and a lot of noxiousness for trees. The dandelion competes with apple trees for resources and has a strong allelopathic effect. The dandelion flowers are eagerly visited by pollinators, including bees. In orchards where intensive chemical protection is carried out using fan sprayers, dandelion flowers are systematically covered with spray, which increases bees’ exposure to plant protection products and the risk of them being poisoned. Turf is planted in the first year of the orchard to prevent soil erosion in hilly areas, and on very fertile soils. Turf is planted on the entire area in special cases, e.g. in older orchards with strongly growing trees and in foothill regions, with heavy rainfall. In such orchards, with a low risk of rodents, slowgrowing weeds such as annual meadow grass, henbit dead-nettle, thale cress, chickweed, which prevent soil erosion and the development of more burdensome plants can be considered as cover crops.

5. Soil mulching

Synthetic mulches – black polyethylene film, black agro-textile, or polypropylene non-woven fabric – and mulch of natural origin – textile and paper waste, cereal and rape straw, sawdust, plant chips, wood bark, manure, brown coal, compost, fruit pomace – shall be used to reduce weed infestation in orchards. Prior to using organic litter rich in cellulose (straw, sawdust, bark) whose layer should be systematically replenished to a thickness of 5-10 cm, additional nitrogen fertilisation should be carried out with its standard (recommended) dose increased by 1/3. Organic mulches reduce soil compaction, level out the temperature and humidity of the soil and provide nutrients as they decompose. Organic litters can be laid throughout the entire belt under the crowns of trees (up to 2 m wide) and, where they are limited, in the form of circles around the trunks of trees about 1 m in diameter. Permanent weeds grow through organic litters and the need for additional control, e.g. with herbicides, must be taken into account. Straw mulch attracts rodents to the orchard. The lifespan of synthetic mulches is of several years, after which they require troublesome disposal (picking up and processing or combustion in incineration plants).

IV. TENDING AN ORCHARD

Prof. dr hab. Waldemar Treder, dr Zbigniew Buler, dr Jacek Filipczak

1. Apple tree irrigation

Because of their relatively long growing period, apple trees have high water requirements. To provide apple trees with the right amount of water in our climate conditions, annual rainfall is required at the range of 550-750 mm. Unfortunately, in many parts of the country the rainfall is much lower, it does not reach even 500 mm. An additional problem is the increasing occurrence of long rainless periods and the intensification of apple production. Currently, most orchards are intensively planted with trees grafted on dwarf rootstocks. Such trees have a relatively weak and shallow root system. If they are planted on light soils, irrigation may be necessary every year. Light soils have low water retaining capacity, which results in limited water availability for apple trees even in relatively short rain-free periods. Lack of water results in a significant reduction in yield, but primarily in the deterioration of fruit quality. Reduced water availability also results in poor tree growth, which reduces yield in the following years. Taking into account water requirements of apple trees and average rainfall in Poland, the maximum water demand for sprinklers can be estimated at 3-3.6 mm/day, and for drip irrigation systems at 2-2.5 mm/day. Unfortunately, in extremely dry years these values can be even higher: 5 mm for sprinklers and 4 mm for drip irrigation. Apple trees can be irrigated with sprinklers, under-tree mini sprinklers or drip irrigation systems. The choice of the type of irrigation depends primarily on the availability of water and energy, the spacing between trees and the technical capabilities of the holding.

Sprinkler irrigation

For good uniformity, sprinkler spacing should be equal to the radius of their range. The frequency of irrigation depends on the size of the plants and the weather pattern, and individual water doses are based on the depth of the root system and the water capacity of the soil (Table 9).

Table 9. Approximate maximum sprinkler doses (in mm*) for apple orchards grown on different types of soil (to water the soil to a depth of 30 cm)

Clays	Sandy clays	Loamy sands	Sands with poor clay content
36	30	24	18

*1 mm = 1 l/m^2 = 10 m^3/ha

The sprinkler system can also be used to cool the fruit during extremely hot weather, and to protect plants from spring frost. Sprinkler irrigation during the frost period can prevent damage to flowers even if the temperature drops down to -5 °C. Special sprinklers, in which springs are covered with caps, are installed in antifreeze installations. When designing crop frost protection systems, it must be noted that the intensity of spraying should be no lower than 3.5 mm/m^2/h (35 m^3/ha/h).

Mini-sprinkling

Mini-sprinkling involves sprinkling the soil surface only near the plants. In the mini-sprinkler system, water is dispersed through small, plastic emitters (mini-sprinklers with an output of 20–200 l/h). Depending on the type of the nozzle used, micro-sprinklers diffuse water in the form of droplets or jets. The type of nozzle used influences the shape of the sprinkled surface. In the case of micro-irrigation systems, emitters are installed in or near tree rows. The sub-crown mini-sprinkler system requires relatively good water filtration because the jets of some mini-sprinklers have a diameter of less than 1 mm. This system does not wet leaves or the space between rows. Mini-sprinklers installed above the tree crowns may also be used to protect flowers and fruit buds from spring frosts. Under-tree mini-sprinklers are mainly used in case of very high iron content or in extensive orchards where trees are planted with larger spacing. It is best that mini-sprinklers not wet tree trunks. Excessive watering can lead to bark and wood diseases.

Drip irrigation systems

Due to its very efficient water management, this irrigation system can be recommended particularly in the case of a limited water source output. Drip lines in which drippers are placed inside polyethylene pipes are used as emitters. In light soils, it is recommended to use drip lines with 50 - 60 cm spacing, in heavy soils, spacing can be up to 70 cm. In flat terrain, cheaper emitters without compensation are used. However, to ensure the necessary uniformity of irrigation in hilly terrain, drip lines with compensation or with the CNL feature (not expending water at low pressures) are used. Recommended maximum length of irrigation flow is based on the emitter, the internal diameter of the pipe, output and the spacing of emitters. The life of a drip line is the result of the quality of the material, the line wall thickness and the operating conditions (e.g. water quality). In orchards, it is recommended to use drip lines with a wall thickness of 0.33 - 1.14 mm. To extend the service life of thin-walled drip lines, they can be placed under the soil surface at a depth of 5 - 20 cm. Placing drip lines under the soil surface increases the risk of emitters being blocked by plant roots, therefore only emitters for which the producer in the technical specification ensures the resistance of installation to root ingrowth are used for deep irrigation. The main disadvantage of drip irrigation systems is that drippers are sensitive to water contamination. The type of pollution depends on the type of water source. Water from open water bodies contains mechanical impurities (sand, dead plant and animal matter) and biological contaminants (algae, bacteria), while water from deep water wells often contains large amounts of Fe, Mn, Ca and Mg compounds that can block emitters. Table 10 contains information on the impact of water quality on the likelihood of clogging of drip emitters.

Table 10. Assessment of water quality for drip irrigation

Factors	**Likelihood of clogging**		
	small	**medium**	**large**
Solids content [mg/l]	<50	50-100	>100
pH	<7	7.0–8.0	> 8.0
Manganese [ppm]	< 0.1	0.1–1.5	> 1.5
Iron [ppm]	< 0.1	0.1–1.5	> 1.5
Bacteria [number/ml]	10 000	10 000-50 000	50 000

The size and type of filtration depend on the water flow and quality. When using water from open tanks, the use of sand filters is recommended. Groundwater can contain high levels of iron, so a water analysis should be performed prior to designing a drip installation. With an iron content above 1.0 mg/L it is advisable to use an iron removal device. A fertiliser dispenser is an important element of an irrigation system. The most common dispensers are proportional mixer pumps and injectors. Dispensers are used to feed fertilisers (fertigation), acidify water or treat systems with acid solutions to dissolve and wash out mineral and organic deposits formed therein. Every irrigation system should be fitted with a check valve to prevent contamination of water source. The frequency of irrigation depends on the weather during rainless periods. Drip irrigation should be carried out relatively often — even daily, but not less often than once every 3 days. A single dose of water for a drip system should be selected so that water does not soak in the soil profile below a depth of 30-40 cm. On light soils, this is usually 10-14 litres of water per emitter. Tensiometers can be used to assess water availability for plants and thus to determine the frequency and necessity of irrigation. The tensiometer is installed in the soil at a depth of about 20-30 cm, at a distance of 15-20 cm from the dripper. Irrigation literature and detailed recommendations and information on water requirements of apple trees are available from the Irrigation Service on the website of the Institute of Horticulture: http://www.nawadnianie.inhort.pl.

2. Shaping and pruning trees and regulating growth and fruiting

Formation of trees

The aim of pruning apple trees is to maintain a proper balance between growth and fruiting. Properly done, pruning allows free air flow and better sunlight penetration within the tree crown. This reduces the risk of disease. Pruning is also an important phytosanitary treatment. The treatment must involve cutting off the shoots affected by fruit tree cancer, bacterial canker, bark canker, powdery mildew or fire blight. In this way, possible causes of plant diseases during vegetation are eliminated. Pruning is an important part of forming crown structure in the early stage of the orchard's life. The correct shape and optimum volume of the crown are essential for the size and quality of the fruit. The shape of the tree crown and spacing of tree planting must ensure that the leaves and growing fruit enjoy optimum sunshine throughout the season. At the same time, the tree crown must be strong to carry the weight of tied fruit until harvest. Dwarf apple trees require permanent supports for this. The tree planting system should aid the producer in reducing the need for herbicides. This enables a system of planting trees in one row. Planting tree rows is on the north-south axis is the most favourable solution.

Tree pruning

Pruning trees after planting

The aim of pruning is to restore the balance disturbed by the uprooting of nursery trees. Prune the planted trees in the spring. This also applies to trees planted in autumn.

If a very good soil site is provided with the possibility of irrigation immediately after planting – biennial trees with a one-year crown or strongly grown and branched one-year old ‘Ekstra’ class maiden perennial trees should be planted. Such trees already have crowns formed at a height of 60-80 cm from the ground, depending on the growth form and habit of the grafted variety. Planting trees already prepared in the nursery results in a significant reduction or even abandonment of pruning after planting. In this case, only shoots growing on the trunk too low (up to 60-80 cm) and forming a sharp angle with a guide hall are removed. If unbranched trees are planted under these conditions (maiden trees or so-called “seven-month-old trees”), they should be left unpruned.

When establishing an orchard on a weaker soil site and without the provision of systematic irrigation, trees in the form of 1-year old maiden trees, unbranched or with 3-4 medium-length side shoots, are recommended for planting. Such trees have a more favourable ratio of root system to aboveground part, resulting in stronger growth in the first year in the orchard. Adaptation of such trees in the orchard is generally very good. On poorly branched trees, all stronger side branches growing at a height of 50-60 cm from the soil surface should be halved. Weak and high-growing shoots should be shortened by two thirds of their length. Branches growing low (up to 60-70 cm from the soil surface) should be cut off. Unbranched trees should be pruned at a height of 70-90 cm from the soil surface. Varieties of the elevated type are shortened lower, and varieties of the spread type - higher.

Pruning growing trees

The intensity and method of pruning must be adjusted to the cultivation system. However, regardless of the shape of tree crowns or the planting density of trees, pruning should maintain the best possible annual fruiting crop and the high quality of apples produced, and ensure optimum budding in the following year. Pruning should be done in such a way that apple trees start to bear fruit as early as possible. Pruning should also ensure the longest possible life of the orchard by keeping the trees healthy.

Timing of pruning apple trees

The main pruning should be done during the winter rest period. The second half of winter is the best period for this. Earlier pruning may increase the susceptibility of trees to frost damage. This leads to an increased development of diseases, mainly of bark and wood.

Winter pruning

It should be carried out systematically, each year and at a moderate level. Too heavy pruning may lead to diseases such as fire blight. When pruning, the shape and size of the tree crown as well as its structure should be adjusted. The conical crown is the most universal. The trunk and lower trunk are the only permanent parts of the crown. Shoots and side branches are replaced. The shoots competing with the guide, located mainly in the upper part of the crown which receives more sunlight, should be removed first. In this type of crown, no shoot can be thicker than or dominate the guide. In the lower part of the crown, up to a height of about 50 cm, shoots and twigs that have dropped low under the weight of the fruit, just above the soil surface, should be removed. After three to four years of fruiting, renewal pruning is recommended. The old and thick branches are pruned at the guide, leaving a short pivot from which young shoots grow over the summer. The guide should be shortened above the support, never too smoothly, with one annual shoot left at its top.

Complementary summer pruning

It is carried out during the vegetation period, in the second half of the summer. Its main aim is to increase sunlight exposure of fruit. Strong, vertically growing annual shoots, or so-called ‘wolf’ shoots, should be pruned first while weaker shoots should be left. The optimum time for this is three weeks before the expected harvest. In some situations, when trees grow too strongly, summer pruning is used to control excessive vigour of shoots. For this purpose, it is possible to shorten this year’s leafy shoots starting from the beginning of July. Summer pruning should be completed by the end of August.

Other methods of regulating the growth and fruiting of trees

Every treatment, other than pruning, which affects the intensity of the growth or the fruit yield, is a regulating treatment. Such treatments include the use of bioregulators and other chemicals allowed by law to be used in the production of apples. These chemicals include preparations that influence the quality of fruit (improving apple colour, reduction of skin russeting, etc.) and/or the stimulation or inhabitation of vegetative growth. Such preparations should be used in case of an actual need, as indicated in the producer’s instructions on the label. Preparations that stimulate growth/vigour of trees should be used with particular care as they may create an environment that favours the development of certain diseases such as fire blight.

Plant protection products should be used in accordance with the recommendations given on the label and in a way that does not endanger human health, animals or the environment.

Thinning flowers/buds

This is important for the quality of the apples produced. It should be done at an optimum time. Chemical thinning should be carried out as specified by the producer on the product label. Only products authorised for use on apple trees may be used. Hand thinning can be done from flowering to the moment when the fruitlets are the size of hazelnuts. Underdeveloped, damaged, and deformed buds should be removed first during treatment. The best buds are left on the shoots, one every 10–20 cm. Each shoot should have between 10 and 30 leaves. Large-fruited varieties should be thinned less severely, leaving fruit buds every 10 cm, while varieties with smaller fruit - at 20 cm intervals.

V. PROTECTION AGAINST DISEASES

Dr hab. Beata Meszka, prof. IO, dr Hanna Bryk, mgr Hubert Głos, dr Sylwester Masny, dr hab. Tadeusz Malinowski, prof. dr hab. Piotr Sobiczewski

1. List of the most important diseases and their characteristics

Fire blight – *pathogen: Erwinia amylovora*

Fire blight is the most dangerous bacterial disease of apple trees. It can be found on all aboveground parts of the tree. More than 130 plant species from the rose family are infected by perpetrator of the disease. Bacteria that overwintered on the edges of cankers and necrosis and in dormant buds are primary pathogens. In spring, the bacteria spread from overwintering sites via wind, rain, insects, etc. Infection of plants occurs through natural openings (stomata, latnicels, nectaries, hydathodes) and wounds. During the growing season, bacteria can survive and reproduce on the surface of plants without infecting plants, being a source of infection throughout the season. The infected flowers wilt rapidly, shrink and die, ranging in colour from orange to brown. First red-brown spots appear on the edges of leaves, around the midrib or between the veins. They enlarge with time, even taking over the whole leaf. Infected leaves shrink and usually fold inwards along the midrib. Young green shoots wilt, turn brown and die, and their tops tend to curve into the shape of a crosier. Infected fruit dry out and shrivel into mummies. There are cankers on twigs, branches and trunks. The bark is initially smooth, slightly swollen and hydrated on the infection side, then grows darker, collapses and dries. At the end of summer, the bark may break in a characteristic way. Cankers usually resemble an ellipse with jagged edges, and sometimes a wedge with the base facing upwards. During the growing season, bacterial ooze – initially greyish white, then yellow and finally amber in colour – may be observed on all infected tissues. Ooze containing millions of bacteria suspended in mucus is an exclusive feature of the fire blight.

Apple scab – pathogen: *Venturia inaequalis*

Apple scab is the most dangerous annual apple tree disease, especially in orchards where grown varieties are susceptible to this disease. There are saprotrophic and parasitic phases in the life cycle of the pathogenic fungus. The pathogen overwinters on the fallen leaves, forming a pseudothecia which are fruiting bodies of the perfect stage. In the pre-spring, sacks filled with two-celled ascospores (sack spores) appear in pseudothecia and provide a source of primary infection in the spring. Ascospores are released in wet weather. The disease develops the fastest during high air humidity, in the temperature range of 17-23°C. Primary infections can last from mid-April to mid-June and even into early July. In the growing season, the parasitic phase of *V. inaequalis begins*. Characteristic spots appear on infected plant parts (leaves, fruits, petioles, sepals, fruit stalks) as a result of the disease. At first they are irregular, velvety, olive-green, and then turn dark brown to black in time, with clearly marked edges. On the surface of the spots, conidiophores are formed with single-celled conidia, which are the source of secondary infections later in the growing season. The leaf tissue adjacent to the ageing spot becomes thinner, deformed and even perforated. Infected fruit undergo deformation where spots occur, usually accompanied by skin cracking. The annual occurrence of apple scab is favoured by abundant and frequent rainfall and the accompanying wetting of herbaceous organs, especially during the primary infection period.

Apple powdery mildew – *pathogen: Podosphaera leucotricha*

Silvered shoots in early spring indicate that they have been severely infected by *P. leucotricha*. In spring, a whitish mycelium with numerous conidiophores and conidia forms on the surface of tissues developing from infected buds. Single-celled spores spread with the wind, and are a source of secondary infections. Severe infection of leaves and shoots leads to inhibition of growth. Chlorosis develops on the upper side of leaves with disease symptoms, and the underside of the leaf blade is covered with a powdery mycelium. The tip of infected shoots usually dries, and buds overgrown by the pathogen become more susceptible to frost damage. Severe weather conditions during cold winters can cause buds to die out. The symptoms of the disease include white powdery secretion on fruitlets. Affected apples gradually become russeted. The severity of the disease depends to a large extent on the susceptibility of the variety.

Grey mould – pathogen: *Botrytis cinerea*

The disease is caused by a polyphage fungus that affects many fruit plants. Apple blossoms become infected during the flowering and falling of petals periods. The first symptoms of the disease include red-purple discolouration of the skin around the sepals on the fruitlet. Then a small rot spot is formed, with a darker and dried perimeter. The flesh is sunken and goes dry at the spots, forming a dry rot. The disease can develop during storage if apple blossoms are infected. The fungus that inhabits the remaining flower portions develops in high humidity in cold storage and forms rot spots around the calyx of the apple. The rot surface is covered with grey shreds of mycelium with conidia that spread by contact to adjacent fruit, giving rise to large nests of diseased apples. The disease causes nest rot of apples in the cold room. The risk of infection is increased by improper storage of fruit (e.g. too high air humidity or wet apples in a cold store). Apples can also be infected through wounds occurring during the pre-harvest period.

Brown rot – pathogen: *Monilinia fructigena*

The disease occurs mainly on fruit, causing rotting. It seldom causes rot of flowers and shoots. Conidia infect apples throughout their growth period. Fruit is infected through mechanical wounds following hail or caused by feeding pests. Brown rot spots appear on infected apples, and compact grey and beige pustules (sporodochia) with conidia on them. Rotting fruit usually drop prematurely or dry out, black mummy-like, and remain on the tree until the next year. If fruit become infected near harvest time, the symptoms of the disease develop during storage.

Apple tree bark canker, bull’s eye rot - pathogen: *Neofabraea alba*

The pathogen develops saprophytically on the surface of dead bark or as a parasite on shoots and fruits. Fungi overwinter on rotten wounds and infected shoots. Primary infections are caused by conidia that form in light grey acervuli. The ascospore stage is of little importance in the pathogen's developmental cycle. Conidia are spread in water droplets, infecting shoots through various types of bark wounds. The symptoms of the disease are dry and sunken necrotic spots on the shoots, similar in shape to an ellipse. Young infected shoots die above necrotic areas. In favourable environmental conditions, fruiting bodies of the conidial stage may develop on dead tissues. The disease is particularly dangerous in nurseries and young orchards.

Fruit may be infected in summer, from June to harvest. Conidia are dispersed from infected shoots to fruit in raindrops. They germinate on the surface of apples, and hyphae penetrate through lenticels. The symptoms of the disease develop only in cold storage. Small rotten spots are formed around lenticels, which grow larger with time and combine to form rot sites of several centimetres. The central part of the spots is dark brown in colour, and their perimeter is slightly lighter in colour. The pathogen grows inside fruit, and makes the flesh adjacent to the infected part of the apple bitter. The skin is sunken at the spots, but remains tense and smooth. Acervuli, from which grey and beige conidia suspension emerges, are formed beneath its surface. Susceptibility to the disease depends to a large extent on the variety grown.

Apple anthracnose – pathogen: *Colletotrichum* spp.

The disease used to be classified as a form of ‘bitter rot’. Due to its increasing prevalence and different aetiology, it has been classified as a distinct clinical entity.

The fungi *Colletotrichum* spp. overwinter on the bark of dead wood, on canker lesions and on mummified fruit. They are also the cause of diseases in other fruit crops (cherry, strawberry, highbush blueberry). During the summer, the fungi produce spores in great numbers and infect apple buds or ripening fruit. Damage to the skin makes the fruit more susceptible to infection, but it is also possible for the fruit to become infected via the lenticel. On autumn apple varieties, or in areas with hot and humid weather, symptoms of the disease may develop whilst the fruit is still on the tree. A rot spot then develops, with a taut skin that often cracks, featuring small raised areas which are clusters of the fungus's fruiting bodies. Usually, however, the fruit is only latently infected, and the symptoms of the disease only become apparent after several months of storage. These are light brown, round, slightly sunken rot spots, which initially look very similar to the symptoms of bitter rot. Under the skin of apples, small acervuli (fruiting bodies of the conidial stage of the fungus) form, from which a characteristic salmon-orange mass of spores is released. Perfect-stage fruiting bodies – perithecia – may also appear, clustered in very small, black groups. There are usually more rot spots on one apple than in the case of bitter rot. Rot spots may also be covered with grey mycelium. The rot spreads very quickly and the fungus produces spores once the apples are removed from cold storage and exposed to higher temperatures (e.g. during distribution).

Fruit tree canker – pathogen: *Neonectria ditissima*

The disease is favoured by the cultivation of varieties susceptible to infection and the location of orchards in frost pockets. Symptoms of the disease include darkening of and sunken bark, and necrosis of shoots, branches and trunks. Mycelium and carmine-coloured fruiting bodies of the perfect stage overwinter at the canker site. During the growing season, large numbers of conidia are also formed, which, spread in droplets of water, are the most important source of infection. Infections are favoured by all kinds of mechanical bark wounds. Shaping tree crowns at too sharp an angle may cause cracking of bark and wood at the base of the branches or even break them. Damaged parts are inhabited by the pathogen. Infection can also occur through leaf scars or scars after fruit has been picked, especially if autumn is long and warm. Compact layers of dead bark are a characteristic symptom in the necrosis area. The pathogen can cause a closed and open form of cancer. The disease causes death of shoots, branches and even whole trees.

Collar rot – pathogen: *Phytophthora cactorum*

The main source of infection are zoospores that spread in the aquatic environment and mycelium that overwinters on plant residues. The pathogen of the disease is a fungus-like organism that also produces resting spores (oospores), enabling it to survive in the soil for many years. Oospores cause infections through stomata, cracks or mechanical damage to the bark. A characteristic symptom of the disease is the presence of typical red-brown spots – initially brown and red, weeping spots where the bark dies, peels off and falls off over time, creating extensive wounds revealing wood – in the rootstock below ground and in the ground part of the trunk. At a later stage of the disease, the phloem becomes reddish-brown to dark brown. The disease can lead to ring-barking of the trunk, contributing to the death of trees. Trees growing on wet and heavy soils are most often infected. Infected tree growth is inhibited. The fruit do not reach the size typical for their type, and leaves, chlorotic in spring, become reddish from midsummer. Apple trees grafted on the following susceptible rootstocks are most often infected.

Viroses and viroid-like diseases of apple trees

All diseases associated with virus infection (viroses) or virus-like agents (phytoplasmas, viroids, unidentified) are transmitted during vegetative reproduction. If at least one of the components used to produce trees in the nursery was infested, the plants produced for planting will also be infested. It is not possible to remove the virus or viroid from the orchard (or nursery) other than together with the infested plant. The most common apple viruses: apple chlorotic leaf spot virus (ACLSV), apple stem grooving virus (ASGV) and apple stem pitting virus (ASPV) are considered relatively harmless to the apple varieties currently grown. However, if introduced into a sensitive rootstock or variety, they can even cause the infested plants to die out. Apple mosaic virus (ApMV) causes chloroses on the leaves of most apple varieties, reduces yield (up to 30%), and worsens quality. Due to the lack of transmission by animal vectors, pollen or to seedlings, it is sufficient to use healthy plant material to eliminate it from orchards. Apple rubbery wood is a serious disease caused by Apple rubbery wood virus 1 (ARWV 1) or Apple rubbery wood virus 2 (ARWV 2). Infected trees of susceptible varieties have a disrupted lignification process which leads to reduced stiffness of young shoots (rubbery). Crop losses are up to 30%. The apple green crinkle associated virus (AGCaV) causes a significant worsening of apple quality. Dark green cavities are observed on the fruit. The flesh adjacent to the cavities is hard. If symptoms are more severe, the fruit is not eligible for sale. Disease symptoms that reduce fruit quality—discolorations, dimples, scarring, cracking—are caused by viroids: Apple crinkle viroid (ACVd), Apple scar skin viroid (ASSVd), and Apple dimple fruit viroid (ADFVd). The ASSVd can be transmitted on unsanitised tools used during care work. Undoubtedly, the most dangerous viroid-like diseases of apple trees is proliferation ('witches' broom mycoplasm') of apple trees caused by phytoplasma ('*Candidatus* Phytoplasma mali'). Trees affected by this pathogen produce numerous shoots growing at a sharp angle and forming characteristic 'brooms'. Fruits are much smaller compared to those from healthy trees. Trees infested with the phytoplasma are very sensitive to frost and prone to apple powdery mildew. The pathogenic agent is transmitted by psylloidea *Cacopsylla picta* and *C. melanoneura*, as well as leafhoppers.

Tomato ringspot virus (TORSV), transmitted by nematodes, is the cause of necrosis at the point of fusion of a graft and rootstock. This disease occurs only in the USA, but ToRSV has been detected in Europe in species other than apple trees which does not preclude its incidence in apple trees growing in this geographical area.

2. Risk thresholds and the manner and date of conducting inspections

The basis for integrated pest management are properly conducted inspections on the basis of which a decision on the application of the protection programme is made. In the case of fire blight, the first symptoms of the disease can only be detected by frequent inspections, which are obligatory under IP of apples. Removing infected parts of trees or entire trees can reduce the spread of bacteria, and thus losses caused by this dangerous disease. Inspections from the end of flowering and in July and the end of August must include all trees, particularly the susceptible varieties. In orchards that are at risk, where the disease has occurred or in the vicinity of the disease outbreak, inspections must be carried out systematically, every 7 to 10 days throughout the growing season.

The primary infection period, about 2-3 weeks after the last ascospores are released, and the autumn inspection after harvesting are the most important dates of inspection in the control of apple scab. Inspections should be carried out on about 10-15 randomly selected trees. Detailed observations (at least every two weeks) should be made during the primary infection period, especially on plots of susceptible varieties and varieties with different vegetative growth. During inspection, leaves, petioles, fruit stalks and fruitlets should be carefully examined. The end of the primary infection period is a particularly important date of inspection, as the further protection of apple trees is based on the results of this inspection. At a later date, inspection may be carried out less frequently, but is particularly necessary after periods of prolonged rainfall.

In the case of apple powdery mildew, assessment of the intensity of shoot infections in primary infections (on 10-15 trees of a given variety) should be carried out at the stages of green or pink bud and at the beginning of flowering when there are first visible symptoms of mildew. Before flowering of the apple trees, if less than 4% of the shoots are infested, their removal is recommended, and for greater infestation a treatment is necessary. The second important date of inspection is the end of June and beginning of July, when the effectiveness of chemical protection can be assessed and a decision can be made on further treatments. They are necessary if more than 30 %-40 % of the shoots are infected.

The control program for the main storage diseases, which are bitter rot and gray mold, is established on the basis of an assessment of fruit infection levels upon removal from cold storage in the preceding season. More than 5% of infected fruit indicates the high level of the source of infection in an orchard, and the need for treatments during the flowering period of apple trees or before harvesting. The number and timing of treatments depend on the susceptibility of the variety and weather conditions during flowering and pre-harvest. It is also possible to use registered fungicides after the fruit has been harvested, in accordance with the instructions on their labels.

Controlling bark canker, fruit tree canker, and collar rot requires that all susceptible varieties of trees be subject to inspection. Symptoms of the first two diseases are more visible in the leafless period and therefore inspection can be carried out during winter pruning. Inspection of young orchards is particularly important. Collar rot should be observed after flowering, when the difference between infected and healthy trees is clearly visible.

3. Types of disease prevention

Rational disease prevention involves, on the one hand, making full use of all available methods to reduce disease risks, and on the other, making the best use of chemical protection products. It is essential to ensure good conditions for plant growth through appropriate fertilisation, pruning trees and selecting a site to meet the requirements of the variety. Limiting the source of infection plays an important role in preventing diseases which includes inspection and removal of infected organs and entire trees. In addition, autumn assessment of leaf infection by the fungus *V. inaequalis* allows for a decision on the necessity of performing a mandatory urea treatment that accelerates leaf decomposition. Therefore, the identification of symptoms of apple scab on the leaves, during the autumn inspection of the orchard, requires a compulsory treatment with a 5% urea solution during leaf drop. Signalling the risk of infection in apple trees, observing the development of pathogens, using meteorological stations, and even simple thermometers and rain gauges is a significant help in proper chemical protection. Weather conditions, especially air temperature and precipitation, have a significant impact on the effectiveness of protection treatments. This applies, among others, to choosing a treatment date that ensures both optimum thermal conditions for the effective action of the applied biological plant protection products and if the treatment interval needs to be shortened due to rainfall. Therefore, it is mandatory to conduct measurements and record daily precipitation throughout the period of use of plant protection products and to record temperature values immediately before and after each protection treatment. The introduction of varieties less susceptible to infection plays an important role in reducing losses caused by diseases.

4. Non-chemical methods of protection against disease

Non-chemical methods are an important element of the integrated plant production system, as they make it possible to reduce the use of plant protection products, thus significantly reducing environmental pollution and risks to consumers. The most important non-chemical methods are:

- Selecting a suitable site, avoiding the establishment of orchards in low-lying areas prone to tree freezing, which often leads to increased susceptibility to apple tree canker or bark canker. The site also determines a microclimate that favours or limits the development of certain diseases. For example, in areas with long-term humidity, more frequent treatments against apple scab are necessary.
- Selecting varieties that have a high level of resistance to disease, especially if conditions in the area are more favourable to their development.
- Pruning trees correctly to increase light penetration and air movement through the crown, which in turn reduces the wetting period of leaves and fruit and thus prevents possible infections. Well-formed tree crowns make it possible to spray trees thoroughly, which is particularly important in controlling the so-called difficult diseases, which undoubtedly include apple scab. Treatment is only effective if the whole tree is well covered with the product, including the top part, and if the preparation enters the crown properly.
- After the occurrence of fire blight, bark canker, and fruit tree canker, removing infested tree organs is mandatory. In the case of fire blight, infected organs should be removed along with a stock of apparently healthy shoots and branches due to the ability of *E. amylovora* bacteria to colonise tissues asymptomatically, even within a few dozen centimetres of the blight. In the case of strong infection, remove entire trees.

- Removing old and wild apple trees and other host plants in the vicinity of orchards, which are a potential source of infection in the orchard.
- Adequate fertilisation, especially with nitrogen, as over-fertilisation with this nutrient leads to increased susceptibility of plants to diseases, prolongs the period of vegetative growth, i.e. the presence of young growth, highly susceptible to infection by pathogens such as: *V. inaequalis*, *E. amylovora*, *or P. leucotricha*. Inadequate fertilisation can stimulate apple trees to grow stronger, also with denser crowns, which provides more favourable conditions for infection.
- Raking out and destroying fallen leaves to reduce pathogens that overwinter in leaves (*V. inaequalis*) and removing and destroying fruit mummies (*M. fructigena*).
- Removing infected shoots in early spring, e.g. to reduce the source of apple powdery mildew.

5. Chemical measures to fight diseases

Plant protection products should be used in accordance with the recommendations given on the label and in a way that does not endanger human health, animals or the environment.

In the case of some apple tree diseases, loss can only be prevented through appropriate chemical protection. To ensure appropriate protection, both the biology of the pathogens and the properties of plant protection products should be known well. Every time a decision is taken to carry out a treatment and choose a fungicide, a thorough analysis of the current situation in a particular orchard needs to be done. First of all, the susceptibility of the variety, the developmental stage of the plant and pathogen, the abundance of sources of infection, weather conditions, properties of the preparation, rotation of compounds with different mechanisms of action and the presence of fungi resistant to fungicides should be taken into account. Chemical control of diseases in Integrated Apple Tree Production is presented in Annex 1.

The list of plant protection products authorised for integrated production is available on the website of the Institute of Horticulture – NRI: https://www.inhort.pl/serwis-ochrony-roslin/ochrona-roslin-rosliny-sadownicze/rosliny-sadownicze-wykaz-srodkow/ and on the Pest Alerting Platform at: https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.html.

Useful information on plant protection is also published in the online HortiOchrona Decision Support System for horticultural plant protection (hortiochrona.inhort.pl).

VI. PROTECTION AGAINST PESTS

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Many species of insects and mites can feed on apple trees, but at least a few/a dozen or so, when occurring in large numbers, may cause losses of economic importance. Tortrix moths, codling moth, aphids (including woolly apple aphids), the European red mite, and more frequently also the red spider mite, apple blossom weevil, apple rust mite and red-belted clearwing have been the most important in recent years and require annual control in many orchards. Recently, the role of species such as apple sawfly, apple and hawthorn sucker, and apple leaf midge has been growing. Some species of leaf-mining pests also appear locally, e.g. ear leaf miner, herbivorous beetles, e.g. the garden chafer, cockchafer, weevils, also San Jose scale, apple mussel scale, apple mealybug, bark beetles (larger shothole borer, shothole borer, pear blight beetle), cossid millers (goat moth and leopard moth), dock sawfly, winter moth, and vapourer moth. If they occur in large numbers, it may be necessary to control them in some orchards. In addition to insects and mites, rodents and wild game (hares, roe deer, deer, elk) are also significant in some orchards. Particular attention should be paid to invasive alien pest species appearing in orchards, as well as to native species which, due to climate change, are altering their status and expanding their range.

1. List of the most common pests and their characteristics

<u>Tortrix moths</u> are moths whose caterpillars damage buds, leaves, flowers, fruitlets and fruit. Only some species may be of significant importance to apple trees, depending on the orchard and year. The most important are:

Summer fruit tortrix (*Adoxophyes orana*). The wings of this moth have a wingspan of 15-22 mm. The forewings are a light orange-brown with an irregular dark reddish or brown mesh-like pattern. Eggs are yellow-green, flattened in shape, 0.8 x 0.5 mm in size. Green-yellow caterpillar with yellow warts, a golden brown head and neck shield; 16-22 mm in length when mature. Dark brown pupae, about 10-11 mm long. Caterpillars overwinter until early spring when they feed on buds and developing leaves, and pupate at the end of the flowering time of apple trees. The first generation of adults emerges during late May to late June or early July. Caterpillars feed until the end of July. The second generation of adults fly in late July and in August to early September, and caterpillars feed in August and September. Caterpillars also damage fruit. Two generations occur per year.

Dark fruit-tree tortrix (*Pandemis heparana*). Adults have a 16-24 mm wingspan. The forewings are brown, brown-grey or rusty with a dark pattern. Light green eggs. A green caterpillar with light warts, yellow-green head, grows up to 25 mm long. The pupa is brownish-black in colour and measures 10–12 mm. Caterpillars overwinter until early spring when they feed on leaf and flower buds. The first generation of adults emerges from early June for about two months. Caterpillars feed in July and August. They damage the lower side of the leaf, and fruit. The second generation of adults fly in late August, and caterpillars feed until fruit is harvested. It is a two-host species.

Bud moth (*Spilonota ocellana*). Adults have a 12-16 mm wingspan. Forewings are dark grey at the base, in the middle part white, and in the peak grey with a visible drawing. Eggs are yellowish-white with a metallic sheen, oval in shape, and measures 0.9 × 0.7 mm. A caterpillar is 9-12 mm long, reddish-brown in colour, with dark, glossy warts. Head and neck shield are black. The pupa is brown and 6–7 mm long. The caterpillars overwinter; they feed in the spring from the time the apple tree buds begin to burst, and pupate in late May and June. Adults emerge from early June for about 2.5 months. Caterpillars are present in orchards from mid-June to late August. Bud moth is widespread, especially in poorly protected orchards. It damages buds, leaves and fruit, and its impact is growing. It is a single-host species.

Cherry-bark moth (*Enarmonia formosana*). Adults have a 15-18 mm wingspan. The forewings are yellowish-brown, covered with brownish-black spots and metallic stripes; the hindwings are dark brown. Eggs are flattened and oval, 0.7 x 0.6 mm in size. The caterpillar is brown or salmon-cream with brown warts and a light brown head; grows up to 8-11 mm long. The pupa is light brown, 7-9 mm long. The caterpillars overwinter under the bark of the trees and resume feeding in the spring. They pupate under bark, and this lasts 2-3 weeks. The adult flies 3-4 months. Females lay eggs on the surface of the bark of trunks and at the base of branches, and hatched caterpillars bore into and feed on the bark. They damage the bark, eat leaves and weaken plants, which even leads to the drying out of branches or whole trees. It is a single-host species.

Rose tortrix moth (*Archips rosana*). It is a moth whose olive-brown wings have a span of approximately 20 mm. Eggs are flat, greyish-greenish, in clusters of the shape of a slightly convex disk, 6-8 mm in diameter. A green caterpillar with a dark brown head, up to 15-22 mm long. The pupa is dark brown in colour and 9-11 mm long. Caterpillars hatch in April, just before trees bloom, damage leaves, and also fruitlets after flowering. Signs of feeding can be most easily seen during and immediately after flowering. Individual leaves are rolled into a roll or bound as 2-3 times together and a caterpillar feeds on the inside by eating leaf tissue. It finishes feeding in June and pupates on a leaf. The moths emerge in June and July. Caterpillars damage buds, leaves and fruitlets in spring. One generation of the pest develops per season.

Codling moth (*Cydia pomonella*). A moth has an about 10 mm long body and wingspan of 16-20 mm. The first pair of wings is brownish-grey with a glossy, black-edged spot at the tip (known as the ‘mirror’). Eggs are transparent, slightly opalescent, then milky white, 0.9 x 1.2 mm in size. The caterpillar is 15 mm long, white with a pink tone, has a brown head and neck shield. The pupa is brown in colour and approximately 10 mm long. Caterpillars overwinter in bark cracks. They pupate in April, and the adults usually emerge in the second half of May and are active for about six weeks. The female lays her eggs on fruit buds, fruit and, in extreme cases, on leaves as well. Caterpillars emerge after 8-12 days, and feed for about three weeks. Fully grown caterpillars leave the fruit; some fall into diapause and some pupate. The second generation of adults emerges in late July and early August. Codling moth caterpillars **damage fruitlets and fruit and cause 'maggoty apples'. It is a very significant pest of apple trees.** There are two generations a year.

Red-belted clearwing (*Synanthedon myopaeformis*). The moth is black, with a red band around its abdomen; it is 10-12 mm long and has a wingspan of 15-22 mm. The wings are transparent, with a black-rust (dark reddish-brown) edging. A cream-white caterpillar with a reddish head that grows up to 20 mm. Caterpillars overwinter under tree bark. Adults fly in June and July. Females lay eggs in bark cracks. Caterpillars feed in tunnels underneath the bark of trunks or branches. In great numbers, they can cause branches, or even whole trees, to dry out. The development of one generation takes two years.

Pear leaf miner (*Leucoptera malifoliella*). Adults have a wingspan of 6–8 mm. The front wings are metallic with spots in copper, black and amaranth colours. Eggs are elliptical 0.3 x 0.2 mm in size, transparent, then celadon. The larvae are light green and grow to a length of 3.5 mm. The pupae are 2.5–3 mm long and are enclosed in white, silky cocoons. Pupae overwinter in cocoons on trunks, branches, spurs and fallen leaves. Adults emerge and lay eggs at the stages of green and pink bud. Larvae hatch at the end of flower petal fall period, feeding in the leaves and causing round mines to be visible on the upper side of the leaves. Fully grown larvae pupate in white silky cocoons, usually on bark or leaves. The second generation of adults emerges in late July.

Banded apple pygmy (*Stigmella malella*). Adults have a wingspan of 4.5–5 mm. The forewings are black with a white band and fringed along the edges. Eggs are elliptical, initially shiny and transparent, later creamy green. The larva is up to 4 mm long, yellowish green, flattened, with a brown head. Pupa approx. 2 mm long, in a yellow, heart-shaped cocoon. The pupae overwinter in the top layer of soil at a depth of 2–3 cm. Adults emerge when the apple trees' flower buds are still green. They usually fly until the end of April, with a peak during the pink bud phase. Females lay individual eggs on the lower side of the youngest leaves. Caterpillars hatch after about 15 days, bite under the skin and feed in the parenchyma to create characteristic narrow, winding mines that are brown and visible on the top of the leaves. After 3 weeks of feeding, the caterpillar falls to the ground and produces puparium. Adults of the second generation fly out in June or July.

Apple blossom weevil (*Anthonomus pomorum*) is a black-grey beetle, 4-5 mm long, with a characteristic long snout. Covers show two lines arranged in a V-shape. Eggs are oval, milky white; the legless larva is whitish-cream in colour with a brown head and grows to about 5 mm. The beetles that emerge at the time that apple buds are swelling and breaking overwinter. Females lay eggs singly into flower buds. The hatched larvae feed on the buds, damaging them. Weevils have one generation a year.

Apple sawfly (*Hoplocampa testudinea*). This is a hymenoptera whose body is about 6-7 mm long, yellow-brown in colour with a black pattern and has two pairs of membranous wings.

Eggs are oval, glassy-white, approx. 0.8-1.0 mm long. White larvae with a brown head, approx. 9-11 mm long. Larvae overwinter in cocoons in the soil. Adult insects emerge just before the apple tree blooms. Females lay individual eggs, cutting the peel of the flower cup. One female can lay 50-100 eggs. The hatched larvae initially feed just beneath the surface of the fruitlets, then burrow into the core. On the surface of the fruit buds, scaly, elongated scars form as the larva moves from one damaged bud to the next. The larvae damage 2-5 fruitlets, some of them fall from the tree, while others remain. Fully grown larvae go into the soil. One generation grows in a year.

Psylloidea:

Apple sucker (*Cacopsylla mali*). Adults are hemiptera, 3.3-4.0 mm in size, light green, then brown and reddish. Eggs are 0.4 x 0.2 mm in size. Overwintering eggs are found on shoots of apple trees. In spring, the larvae feed on and suck sap out of the developing buds. Adults emerge in May and feed on the undersides of leaves near the midrib. Females lay eggs that overwinter in September and October.

Hawthorn sucker (*Cacopsylla melanoneura*) and **Cacopsylla picta** (*Cacopsylla picta*). The female of *C. melanoneura* is a hemiptera, 3-3.3 mm in size, initially orange in colour, then dark brown with a reddish tint. *Cacopsylla picta* is light green, with yellowish bands on the thorax, then darker, 2.9-3.4 mm in size. Larvae are smaller, 1.6-2.2 mm in size. Adults overwinter on coniferous plants. In spring, they migrate to apple trees (*C. melanoneura* – late March and early April, *C. picta* in the first week or so of April and in mid-April). The larvae feed on apple trees until the end of May and early June, and then the adults migrate mainly to coniferous plants.

Aphids:

Rosy apple aphid = Blue bag (*Dysaphis (Pomaphis) plantaginea*). The wingless aphid reaches a length of about 2.5 mm. Its body, covered with a waxy coating, ranges in colour from dark pink through blue-grey to brownish. Winged individuals have a body length of 1.8–2.4 mm, with a black head, thorax and siphons, and a dark green-brown abdomen. Eggs are black, shiny and oval shaped, about 0.6 mm in length. This aphid is heteroecious; it completes its life cycle on two different host plants: apple and plantain. Overwintering eggs are found on shoots of apple trees. Larvae hatch in early spring and feed on apple trees, forming colonies on the lower side of a leaf. They suck sap from plants and damage the youngest leaves, which curl. This aphid also damages fruitlets, which are small, deformed, remain on the tree, sometimes a few in a compact cluster. Aphid excreta develop ‘sooty’ fungi of the genus *Capnodium* which inhibit photosynthesis and, by blocking the stomata, impede gas exchange. In summer, winged adults emerge and fly to the secondary host, a different species of plantain, e.g. broadleaf plantain. However, it happens that part of the population remains the entire season on the apple tree. There can be 8-10 aphid generations on an apple tree each year.

Apple-grass aphid (*Rhopalosiphum insertum*). The leafless aphid is about 2.5 mm in length, and is green with green cornicles and tail. Winged aphids are about 2.4 mm long, green, with two dark spots on the pronotum and spots on the abdomen. Eggs are black, shiny and oval shaped, about 0.6 mm long. This aphid is heteroecious. Eggs overwinter on shoots of apple trees, larvae emerge in early spring and feed on leaves. The aphid has only one generation on the apple tree, because after the trees bloom it flies to cereals, and in autumn flies back to the apple tree to lay eggs.

Woolly aphid (*Eriosoma lanigerum*). The wingless form of the aphid is 1.8–2.3 mm long, is dark blue-brown or dark brown in colour, and its body is covered with a fine, white waxy coating. It feeds in colonies which appear covered with filamentous cotton flocs. The winged form is brownish-black. Aphids can be found in bark cracks on the trunk and thick branches; colonies are often found on thin shoots and twigs, as well as on 'wolf' sprouts and root suckers, petioles and pedicels. Aphids suck the sap from plants, weakening them and thereby stunting their growth and hindering their proper development. Large numbers of colonies on the shoots make harvesting the fruit difficult, as they soil both the crop and the pickers. The second stage larvae usually overwinter on the root neck, roots or in bark diverticula and slots. There can be 9-10 aphid generations each year.

<u>Mites:</u>

Apple rust mite (*Aculus schlechtendali*). It is a spindle-shaped mite, approximately 0.16 mm long. Summer forms of females (the so-called protogynne) appear first in the season and are straw-coloured, while wintering females (the so-called deutogynne) develop later, are clearly darker and associated with the further stage of the development cycle. Eggs are small, spherical and colourless. Larvae are similar to adult Eriophyoidea, but slightly smaller. Females overwinter in buds, under bud scales, in bark cracks on spurs. In April and early May, they begin to feed on leaves, flowers and the skin of fruitlets. Feeding of the pest causes a decrease in photosynthesis performance which results in weakening of the plant. The leaves turn grey and become boat shaped. Feeding on flowers can cause russeting of fruit. They cause the greatest damage in nurseries and young orchards. There are 5-6 generations in the growing season.

Apple-blister mite (*Eriophyes mali*). Tiny Eriophyoidea, white, elongated, about 0.2 mm long. The egg is spherical and glassy. Larvae are similar to adult Eriophyoidea, but smaller. Females overwinter in buds, under bud scales. At the turn of April and May, the first generation of Eriophyoidea feed on buds, and the next generations of the pest develop within the blisters on the underside of leaves. 3-4 generations of Eriophoidea occur per year.

European red mite (*Panonychus ulmi*). The female's body is oval and about 0.36 mm long, reddish-brown, with long bristles that arise from bright tubercles. The male is slightly smaller, about 0.26 mm long and rhomboid in shape. Larvae and nymphs are slightly smaller than adults. Overwintering round red eggs are found on the bark of branches, limbs and trunks. If populations are high (there are about 1 500 eggs per 1 cm^2), there are characteristic red eggs deposited on sprouts. Larvae hatch during the green/pink bud stage, feed on buds and on young and then older leaves. Mobile stages of red mites suck sap from cells. Strongly damaged leaves turn yellow, dry and fall down, which weakens the tree, deteriorates fruit quality and causes poor production of flower buds the next year. The female lays 20-90 eggs on the underside of leaves. Generations develop in 21-35 days, depending on the temperature. European red mites have five generations during the growing season.

Red spider mite (*Tetranychus urticae*). A small mite, a female is about 0.5 mm in size, a male is slightly smaller. The female's body is oval. Wintering females are brick-orange, in the summer they are yellow-green with two darker spots on the sides. The male is rhomboidal in shape. Eggs are spherical, about 0.13 mm in size, yellowish. Larvae are slightly smaller than adult mites, yellow-green, with three pairs of legs. It is a polyphagous species. Females overwinter in bark cracks, and in plant residues under trees. They start feeding on buds and young leaves in April. Females lay eggs on the lower side of the leaf blade. Spider mites feed mainly on the underside of leaves, suck sap from cells, weaken plants, cause yellowing of and drying out of the leaves, and premature leaf drop. Five to six generations of red spider mite develop over one growing season. Similar damage is caused by the **hawthorn spider mite**.

Apple leaf midge (*Dasineura mali*). A fly of about 1.5-2.5 mm in size, dark brown in colour with black spots and characteristic long legs. Larvae are white or creamy when young, but become pink when mature; 2.5-3 mm long. Larvae overwinter in the soil and mulch before pupating in the spring. The first generation emerges in April or May. The female lays eggs on the edges of the youngest developing leaves. Larvae hatch in 3-5 days and feed along the margins of leaves causing leaves to develop thickening and inward curling. The infested leaves are strongly deformed and dry out. Larvae feed for 2-3 weeks and then, fully grown, drop to the ground to pupate. The apple leaf midge causes the greatest damage in young orchards, nurseries and vegetative rootstock nurseries. Three generations occur per year.

Leafroller weevil (*Rhynchites (Rhynchites) bacchus*). 4.5-6.5 mm long beetle, purple red with a golden tone, with grey or brown hairs. Eggs are oval milky-white, 1.0 x 0.7 mm in size. The larva is creamy-white, crescent-bent, grows up to a length of 3-6.5 mm. The pupa is creamy-white, approximately 7 mm in size. Beetles overwinter mainly in bark cracks and mulch. In spring, they feed on buds and leaves; females then lay eggs in the cavity of the fruitlet, then cover the hole with excrement, thereby introducing spores of the genus *Monilinia* which causes the fruit to rot. Larvae develop in the fruit, damaging it. They finish feeding by the end of June, come out of the fruit, dig into the soil and pupate. Most beetles appear in autumn and some appear only in spring. Some larvae overwinter for two years. One generation grows in a season.

Plum borer *(Involvulus (Involvulus) cupreus)*. A beetle – 5-8 mm long, brown, with a copper-red gloss, covered with hair. Eggs are oval, whitish, and about 1 mm in size. The larva is white-yellow, crescent-bent, about 5 mm long with a pale brown head. The pupa is creamy in colour and is 4-5 mm long. Beetles overwinter. They feed on buds and leaves in spring. From the second half of May to July, females lay eggs on fruitlets. Before laying the egg, females drill holes into the stem of the fruitlet, which breaks, wilts and falls to the ground. Larvae developing in fallen primordia after completing the development bored into the soil, build a cradle of soil particles and pupate. One generation of the pest develops per season.

Winter moth (*Operophtera brumata*). The flightless female moth is brown-grey, with a thick abdomen, 8-10 mm long, and has vestigial wings. The male is brownish-black and has a wingspan of 20-25 mm. The eggs are oval, yellow-orange, and about 0.5 mm in size. Yellow-green caterpillars, with three white stripes on the sides, three pairs of legs located on the front segment of the body and two pairs of legs on the last segment, which makes them move like the letter omega. They grow to 25 mm in length. The pupa is light brown, 8-10 mm long. Overwintering eggs are found on shoots, near buds. Caterpillars hatch in April and feed on buds, flowers and leaves until mid-June. They can cause partial to complete defoliation and damage to fruitlets. Fully grown caterpillars pupate in the soil. Females lay eggs at the end of October and in November. Each season, one generation of the pest develops.

Vapourer moth (*Orgyia (Orgyia) antiqua*). Females are wingless, yellow-grey, oval, about 20 mm long. Males have wings that span 25-30 mm, are rust brown, with a dark pattern and a white spot. Eggs are ball-shaped, measuring approx. 9 mm in diameter. An ashy caterpillar with white, longitudinal lines and bright red spots on each segment and characteristic brushes of yellow hair placed on the back from 4 to 7 segments. In addition, the caterpillars have two brushes of long black hair at the head and sides of the 5th segment as well as one on the 11th segment. The pupa is brown. Overwintering eggs are found deposited on a piece of leaf and the remains of the pupal cocoon. Caterpillars feed on leaves from April to June, and can cause partial to complete defoliation. They pupate on plants, and moths emerge in July. Caterpillars of this generation feed on leaves, and pupate in September; females lay eggs at the end of September and in October. Two generations occur per year.

Cockchafer (*Melolontha melolontha*). This elongated beetle is 20-25 mm long, black, with rows of white, triangular spots on the sides of the abdomen. Large fan-like elytra. Antennae and legs are brown. The eggs are yellowish, laid into the soil in clusters of 25-30. The larva, called a grub, is bent in a horseshoe shape, creamy white, with a large brown head and three pairs of prolegs, about 50 mm long when full-grown. Damage is caused by larvae, called grubs, which feed on the roots of the plants, destroying them. They can cause the death of young or even several-year-old trees. Occasionally, damage may be caused by beetles feeding on the leaves and leaving them stripped bare. The complete development of the pest takes 3-4 years.

Garden chafer (*Phyllopertha horticola*). The beetle is 10-12 mm in size, chestnut-brown in colour, the head and pronotum are green-blue and shiny. Eggs are oval and yellowish, larva is cream-white, similar to the young Cockchafer grubs, grow up to 2 cm in length. The larvae overwinter in the soil. Beetles emerge at the end of May and in June. They feed on leaves and can damage fruitlets. They are very active on sunny and warm days, and can be seen on grass between rows and on weeds. Eggs are laid in the soil, and larvae feed on the roots of grasses and weeds, and also on the roots of crops.

Armored scale (*Diaspidiotus perniciosus = Comstockaspis perniciosa*). The female's body is pear-shaped, 1.5-2.0 mm long, covered with a shield that is round and slightly convex, colours often similar to the bark of the tree on which it feeds. Males are winged, the first pair of wings is normally developed, the second is reduced. The larva of the female is pear-shaped, covered with a round dark grey shield, and the male's larvae shield is elongated. The first stage larvae or fertilised females overwinter. Larvae start feeding again in spring. Females give birth to larvae that roam the plant in search of a suitable place to feed and lead a sedentary lifestyle. San Jose scale inhabits mainly the woody parts of the plant, but in the summer it also feeds on leaves and fruits. San Jose scale feeding worsens the quality and commercial value of the fruit and disqualifies it in practice. Two generations develop in the course of the growing season.

Apple mussel scale (*Lepidosaphes ulmi*). The female has a pear-shaped body, about 1-2 mm long, milky white, with no wings or legs. Its body is covered by a grey or grey-brown shield 2.0-3.5 mm long, in the shape of a comma. A winged male can fly to other trees. Eggs are elongated, approximately 0.3 x 0.15 mm long, white or creamy. The larva in the first stage of development has the shape of an oval, flat, yellowish dial, 0.3 mm long, with three pairs of legs. The stage II larva is legless, covered with a brownish shield. White eggs under brown shields of females overwinter on trunks, branches and branches. Larvae hatch shortly after the apple tree blooms. They come out from under the shields and insert their spike into the bark tissue. Adult larvae and insects suck juices from the cells of the plant. High incidence of apple mussel scale leads to deformation and drying of inhabited and damaged organs. One generation of the pest develops a year.

Apple mealybug (*Phenacoccus Aceris*). Female is oval, 3-4 mm long, green, with a delicate wax secretion. It is incapable of flight. The male, like other scale insects, has a delicate structure and one pair of wings; it can fly. Eggs are oval, 0.3 mm long, lemon-yellow. Eggs are laid on trunks, branches, leaves and in forks of the branches. There can be hundreds of eggs in each trunk. Lemon-yellow larva, with bright, red eyes. The second stage of developmental larvae overwinters in bark cracks or slots. In early spring, they leave the winter habitats and begin feeding. The apple mealybug sucks juices from the cells of leaves, shoots and branches which weakens the trees and can cause premature fall of the leaves.

Bark beetles:

Larger shothole borer (*Scolytus mali*). The adult insect is a beetle, cylindrical shape, about 4 mm long, shiny, dark red brown. Eggs are yellowish, and the larva is legless, white with a brown head. Larvae overwinter under tree bark in drilled out hollow corridors. After eclosion (pupation) (most often in May), the beetles fly out. Females bite into the trunks or branches, drilling the corridors in which they oviposit. Hatching larvae drill side corridors to form a large feeding ground. Entry holes 1–2 mm in diameter can be seen on the bark of the trunks and branches. Beneath the bark lies a feeding chamber consisting of a main tunnel and lateral tunnels running perpendicular to it, which have been burrowed by the larvae. There are two generations a year. The second generation beetles usually occur most often in July-August.

Shothole borer (*Scolytus rugulosus*). A beetle 1.5-3.0 mm long, matte, with dark brown shields and pronotum. The larva is white and up to 4 mm long. Larvae overwinter in small pupa chambers. There are two generations a year. Beetles appear most frequently in May and July. Females bite into the trunks or branches of trees, drill corridors in them, and oviposit in the so-called breeding cavities. Small openings of 1–2 mm diameter can be observed on the trunk and branches. Up to 20 side passages branch off from the short (1-4 cm) main passage.

Pear blight beetle (*Xyleborus dispar*). This beetle has dark brown elytra and a very prominent, almost black pronotum. Female is 3.0-3.5 mm long, while the male is smaller – 1.5-2.0 mm – and is incapable of flying. Eggs are oval, measuring 0.8–0.9 x 0.4 mm, and pearl-white. Larva is legless, white. Adults overwinter. In April and May, beetles fly out. When searching for suitable places to lay their eggs, the females gnaw into the shoots and trunks of trees, burrowing a short tunnel perpendicular to the axis of the shoot, which then curves to form a full circle. Lateral corridors start from the main corridor shaped in this manner. One female lays between 30 and 40 eggs, and the larvae that hatch from them feed on the mycelium of symbiotic fungi *Ambrosiella hartigii*.

<u>Cossid millers</u>:
Goat moth (*Cossus cossus and*). The moth is light grey in colour, with dark, transverse stripes and a wingspan of approximately 70-100 mm. Its entire body is covered in dense, greyish hair, whilst its abdomen is lighter in colour, with distinct segments. Egg is 1.7 mm long, light brown, oval, with dark stripes. Caterpillar up to 80-100 mm long, body creamy at the bottom, red or yellow red on top. The head, shield and torso legs are black. Pupa 50-60 mm long, brown. Caterpillars overwinter for 3-4 winters in a corridor drilled in wood along the trunk or in thicker tree branches. The moths fly out at the end of June, July and even August – mainly in the evening. On the trunks, holes in the bark are visible where the caterpillars feed, through which sawdust-like caterpillar droppings can ooze out. Corridors are quite extensive which weakens the tree and causes it to dry. The younger the tree is attacked, the faster it dies.

Leopard moth (*Zeuzera pyrina*). A moth with white wings, spotted across the entire surface with bluish, round spots. The wingspan is approximately 45-70 mm. In individual segments of the abdomen, dark blue rings are visible. Eggs are about 1-1.3 mm long, light yellow, laid individually on buds and young shoots. Caterpillar up to 50-70 mm long, body yellow with dark warts, a dark head and shield. Pupa about 25-40 mm long, red or brown yellow, with a ring of small spikes at the end of the abdomen. Caterpillars overwinter in a corridor drilled usually in the wood trunk. Moths appear from the end of June to August, and they fly out mainly at night. Dying shoots can be seen on trees infested by the pest above the place where the caterpillar feeds. Entrance holes of the caterpillars and the sawdust droppings falling out of them can be seen on trunks. A corridor can be up to 35 cm long and about 10 mm wide.

Dock sawfly (*Ametastegia (Ametastegia) glabrata*). A parasitic fly, 6-8 mm long, two pairs of membrane wings, black, with a purple shade. Eggs are white, kidney-shaped, laid on leaves of smartweed, sorrel, or quinoa. The larva is approximately 13-18 mm long. The head is light brown or brown. Eyes very well visible, black, surrounded by a black border. Larvae overwinter in the thick parts of the stems of herbaceous plants close to the ground, seldom in the core of one-year apple tree shoots. Larvae of summer (2nd) generations emerge in September and October. Seeking places to overwinter in weedy orchards in late summer and autumn, they may wander onto the fruit, bite into it and bore narrow corridors of varying lengths towards the seed nest. Larvae can also bite into the one-year apple tree shoots – then they drill corridors in the core and stay there for overwintering. Just before and during the harvest—in August, September, and October—small, round entrance holes about 2.5–3.0 mm in diameter, surrounded by a pink ring, can be observed on the surface of infested apples. They resemble the entry holes made by the apple fruit moth's caterpillars, but no pest droppings are visible inside them. Even several holes can be seen on a single fruit through which the larvae have bitten into it. They drill narrow, generally shallow corridors in the flesh. They can be seen after cutting the fruit – they are usually empty, only some may contain green larvae of the dock sawfly. Dock sawfly develops two generations a year.

Small rodents (common vole and European water vole) can cause serious damage in some areas and years. Young orchards are most at risk, but not exclusively. Common voles are abundant every few or a dozen or so years. They gnaw the roots and root collars of trees, and can cause the death of old trees and damage entire orchard plots. The European water vole also gnaws the bark from the roots and causes the trees to weaken and die.

Game (hares, roe deer, deer, elk). Wild game causes great damage to apple orchards. In unprotected or improperly protected orchards, damage caused by game may include from a dozen to several dozen percent of trees. Young trees are most vulnerable to damage. Bite marks in the trees are also recorded in older plantings, but they are somewhat smaller as the threat of this type of damage decreases significantly with age.

2. Risk thresholds and the manner and date of conducting inspections

Orchard inspections should be performed every 7-14 days starting from the leafless period. Particular attention should be paid to the spring period when trees are particularly vulnerable to damage by agrophages. This applies in particular to pests such as: spider mites, aphids, tortricidae, psylloidea, apple blossom weevil and apple sawfly. It is mandatory to hang traps with pheromones in the orchard, to monitor for the occurrence of cherry bark moth, red-belted clearwing, codling moth and summer fruit tortrix, dark fruit-tree tortrix, bud moth, as well as hanging white sticky traps to monitor for apple sawfly in order to determine the need to control these pests and determine the optimal deadlines for carrying out the control procedures. Traps should be suspended in the orchard before the date set for inspection (Annex 2). Traps should be applied in accordance with the recommendations of their producer and taking into account the environmental conditions of a particular orchard (including the selection of varieties, severity of pest infestation in adjacent orchards, pest abundance in orchards in past seasons).

Chemical pest control measures should only be carried out when the population of a particular species exceeds the threat threshold. The decision to carry out a treatment in a particular orchard should be preceded by a comprehensive analysis, taking into account, amongst other things: the current price of fruit, the costs of plant protection products, their effectiveness, the phenological stage of the apple trees, and the variety being grown. Particular attention should be paid to situations where several species of pests are present at the same time, along with their natural enemies. The correct phytosanitary diagnosis of the orchard and the correct determination of the moment of intervention are crucial for the effectiveness and rationality of chemical protection.

The risk thresholds for the most common apple pests and the observation dates are set out in Annex 2.

3. Non-chemical pest control methods

Non-chemical methods of pest control involve the use of various approaches to pest management, including mechanical and biological methods, cultivation practices, habitat management and others. The biological method is based on the use of predators and parasites to control pest populations. Cultivation practices focus on the use of a variety of agricultural techniques (e.g. disc harrows and rotary tillers, which help to control grubs) to make the environment less favourable to pests. Mechanical methods (e.g. traps and barriers in the form of nets) make it difficult for pests to inhabit crops. Habitat management, on the other hand, involves shaping ecosystems in such a way as to encourage beneficial organisms to colonise a given area and thrive there.

In the cultivation of apple trees, non-chemical methods of pest control/reduction include:

- if grubs are found, the soil should be mechanically tilled several times and buckwheat or mustard should be grown before establishing the orchard. This treatment prevents or impairs the development of grubs. Mass catching of cockchafer beetles in light traps can also be used which reduces the number of laid eggs,
- collecting and destroying egg clusters – such as those of the vapourer moth, the rose leaf-roller and other harmful butterfly species – during spring pruning of orchards,
- the use of microbiological preparations to control codling moth and tortrix moths. If several eradication procedures must be carried out, at least one of them must be performed with a microbiological agent,
- the use of the male disorientation method to control codling moth and tortrix moths,
- the introduction into orchards of the predatory mite (*Typhlodromus pyri*; Phytoseiidae), which effectively reduces the population of spider mites and Eriophoidea. These mites can be carried from one orchard to another on the long shoots they inhabit. Predatory mite is also available from specialised companies in the form of felt bands containing overwintering females. The bands are placed on the trunk or shoots of trees in winter or early spring, ensuring they fit snugly against the

surface. The presence of predators on the leaves should be checked at the same time as monitoring for spider mites and Eriophoidea,

- the attracting of birds of prey. To this end, support poles at least 4 m high, with a crossbar at the top measuring 40-60 cm in length, should be erected in the orchards. At least 1 pole should be set to 5 ha, and in the case of larger plantations – several poles. The poles should be placed on the edge of the orchards and must not be obscured by other trees that could distract birds of prey from landing on the poles,
- setting of tick, pipe and conical traps for the harvesting of the earthworm artefact,
- it is necessary to create favourable conditions for the development and survival of useful species of insects, mites and other arthropods (care for mid-field tree-planting, bush-planting, nesting boxes for birds),
- setting up houses for mason bees and hatching booths for bumblebees. For mason bee houses, there should be at least 200 nesting channels in the structure,with a diameter of 5-8 mm and a length of 14-20 cm. At least 70% of the nesting material (nesting channels) should be cut up cane tubes. The other material used in the houses may be other hallow cut plant stalks or drilled blocks of wood with the above parameters. For bumble bees, it is recommended that roofed wooden nesting boxes measuring approximately 20x15x10 cm with an entrance hole of 2 cm in diameter be displayed. Inside the box, material should be provided for the construction of an external nest, e.g. worn dry grass. Boxes can be placed on the ground, above the ground or by creating ‘mounds’ i.e. burying boxes halfway into the ground. The entrance to the nest should be easily accessible, not overgrown or obscured. The preferred place to place the box is on the edge of an orchard.

4. Chemical protection against pests

Pest control using chemical products should be applied only if the number of pests reaches or exceeds the risk threshold.

Pest control should be carried out with products selective or partially-selective toward beneficial mites and insects. To prevent the development of resistance to active ingredients of insecticides and acaricides, a rotation system should be used. Attention must be paid to the maximum number of sprays with a particular preparation against a particular pest as well as the maximum number of treatments with a particular preparation in apple tree cultivation. Protection of apple tree should include protection enhancers (preparations containing natural oils, silicone compounds, polysaccharides, etc.) whose mechanism of action is to create physical barriers that limit the development of pests. If it is necessary to control spider mites, scale insects or aphids, at least one treatment must be carried out using a product with a mechanical/physical mode of action.

Plant protection products should be used in accordance with the recommendations given on the label and in a way that does not endanger human health, animals or the environment.

The list of plant protection products authorised for integrated production is available on the website of the Institute of Horticulture – NRI: https://www.inhort.pl/serwis-ochrony-roslin/ochrona-roslin-rosliny-sadownicze/rosliny-sadownicze-wykaz-srodkow/and on the Pest Alerting Platform at https://www.agrofagi.com.pl/143,wykaz-srodkow-ochrony-roslin-dla-integrowanej-produkcji.html.

Useful information on plant protection is also published in the online HortiOchrona Decision Support System for horticultural plant protection (https://hortiochrona.inhort.pl/).

VII. HYGIENE AND HEALTH RULES

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

A. **Personal hygiene of workers**

1. Persons involved in the harvest and preparation of produce for sale should:
   a. not be a carrier of, or suffer from, diseases that can spread through food;
   b. maintain personal hygiene, observe hygiene rules, and in particular wash their hands often during work;
   c. wear clean clothing and, where necessary, protective clothing;
   d. treat injuries and abrasions with a waterproof dressing.
2. The fruit producer ensures that the workers that participate in the harvesting and preparation of fruit for sale:
   a. have unlimited access to washbasins and toilets, cleaning products, paper towels or hand dryers, etc.;
   b. have undergone hygiene training.

B. **Hygiene requirements for crops prepared for sale**

The plant producer must take appropriate measures to ensure that:

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

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

Under integrated plant production, the producer takes the necessary actions to ensure that:

a. cleanliness of rooms (and equipment), means of transport and packaging is maintained;
b. order is maintained on driveways and around buildings where merchandise is stored and prepared for trade;
c. farm and domestic animals are not allowed into rooms, vehicles, and packages;
d. harmful organisms (agrophages and organisms dangerous for humans) which may lead to contamination or pose a threat to human health, e.g. mycotoxins are eliminated;

e. hazardous waste and substances are not stored together with crops prepared for sale.

VIII. LIST OF MANDATORY ACTIVITIES AND PROCEDURES IN THE INTEGRATED PRODUCTION SYSTEM OF APPLE TREE

Basic requirements (100 % compliance, i.e. 20 points)			
Item	**Control points**	**YES/NO**	**Comment**
1.	Analysis of soil from each plot in terms of reaction, organic matter content, and digestible phosphorus, potassium and magnesium – on light soils at least once every 3 years, and on heavier soils – at least once every 4 years (see Chapter II.1).	❑/❑	
2.	The use of deacidifiers, mineral/organic fertilisers or soil-enhancing agents containing nitrogen, phosphorus, potassium and/or magnesium, solely on the basis of the results of soil and leaf analysis, and visual assessment of the plant condition (see Chapter II.3-5).	❑/❑	
3.	The use of mineral fertilisers containing the necessary micronutrients, based on the results of leaf analysis or visual assessment of leaves and fruits (see Chapter II.5).	❑/❑	
4.	The use of herbicides only under the crowns of trees. The width of the herbicide strips should not exceed 1.80 m (see Chapter III.2).	❑/❑	
5.	It is forbidden to use soil herbicides in orchards older than three years (see Chapter III.2).	❑/❑	
6.	In the event of fire blight, bark canker, and fruit tree canker, organs or whole trees should be removed (see Chapter V.4).	❑/❑	
7.	If scab spots are observed on the leaves during the autumn inspection of the orchard, immediately after leaf fall begins, treat the trees with a 5 % urea solution to control the source of infection caused by	❑/❑	

	Venturia inaequalis (see Chapter V.3).		
8.	Removal of trees infested with phytoplasma proliferation (‘witches’ broom mycoplasm’) of apple trees (see Chapter V.1).	❑/❑	
9.	Monitoring of the orchard for the presence of diseases (fire blight, apple scab, apple powdery mildew, bitter rot, grey mould, bark canker, fruit tree cancer, ring rot of the base of the fruit tree trunk). The frequency and method of monitoring are performed in accordance with the guidelines described in the Integrated Apple Tree Production Methodology (see Chapter V.2).	❑/❑	
10.	Regular monitoring, from early spring onwards, of pests (spider mites, aphids, tortrix moths, psylloidea, apple blossom weevils, apple sawfly) if they occur in the orchard. Observing the frequency and method of monitoring in accordance with the guidelines described in the ‘Integrated Apple Tree Production Method’ (see Chapter VI.2 and Annex 2).	❑/❑	
11.	The decision on the need to perform a pest control treatment is made on the basis of risk thresholds, taking into account, in the first place, pre-flowering treatments (see Chapter VI.2 and Annex 2).	❑/❑	
12.	Inclusion of preparations with mechanical/physical action in the control of spider mites, rust mites, and aphids (at least one of the performed treatments should be carried out using such a preparation) (see Chapter VI.4).	❑/❑	
13.	Introduction and monitoring for the presence of introduced predatory mites (Phytoseiidae) (see Chapter VI.3).	❑/❑	

14.	Monitoring for the European cherry bark moth, red-belted clearwing, codling moth, fruit tortrix, dark fruit-tree tortrix and bud moth should be executed using pheromone traps (see Chapter VI.2 and Annex 2).	❑/❑	
15.	Inclusion of registered microbiological preparations in the control program against pests such as the cherry bark tortrix, codling moth, summer fruit tortrix, rose tortrix, and eye-spotted bud moth (at least one of the treatments should be carried out using such a preparation) (see Chapter VI.3).[1]	❑/❑	
16.	Monitoring of the incidence of apple sawfly using white sticky traps (see Chapter VI.2 and Annex 2).	❑/❑	
17.	Creating suitable conditions for the presence of birds of prey, i.e. setting up at least 1 resting pole per 5 ha and, in the case of larger plantations – several poles per hectare (see Chapter VI.3).	❑/❑	
18.	Placing mason bee houses or mounds for bumblebees at a frequency of at least 1 per 5 ha, and in the case of larger plantations – several pieces (see Chapter VI.3).	❑/❑	
19.	Recording daily rainfall totals over the entire period of application of plant protection products (see Chapter V.3).	❑/❑	
20.	Recording the temperature values immediately before and after the plant protection treatment (see Chapter V.3).	❑/❑	
	Total points		

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

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

IX. CONTROL LIST FOR FRUIT CROPS

Basic requirements (100% compliance, i.e. 27 points)			
Item	**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 only use plant protection products included in the list of IP- of approved products and approved for the given crop?	❑/❑	
4.	Are all the documents specified in the methodology and logbook (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?	❑/❑	
9.	Is every application of a plant protection product recorded in the IP logbook, 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?	❑/❑	

Basic requirements (100% compliance, i.e. 27 points)			
Item	**Control points**	**YES/ NO**	**Comment**
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, being exceeded (if the IP methodology imposes stricter requirements than the label, we shall comply with the provisions of the IP methodology)?	❑/❑	
19.	Were the sprayers listed in the IP logbook in working order and did they have valid technical approval 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 separate space for filling and cleaning the sprayers?	❑/❑	
22.	Are plant protection products stored in a marked closed room in such a way as to prevent contamination of the environment and protect	❑/❑	

Basic requirements (100% compliance, i.e. 27 points)			
Item	**Control points**	**YES/ NO**	**Comment**
	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 terms of its form, type, date of application, dose, location and surface?	❑/❑	
26.	Did 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 plant producers (minimum 50% compliance i.e. 5 points)			
Item	**Control points**	**YES/NO**	**Comment**
1.	Is each quarter/field marked according to the entry in the IP notebook?	❑/❑	
2.	Are fertiliser application machines maintained in good working order?	❑/❑	
3.	Do fertiliser application machines allow for accurate dose adjustment?	❑/❑	
4.	Are fertilisers stored in a separate and specially designated room in a manner that ensures protection of the environment against contamination?	❑/❑	
5.	Does the producer protect empty PPP packaging against unauthorised access?	❑/❑	

6.	Is the presence of predatory mites, Chrysopidae, ladybirds and other predators in the orchard recorded?	❑/❑	
7.	Does the producer have a properly equipped space for collecting waste and rejected crops?	❑/❑	
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)			
Item	**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		

X. FURTHER READING

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XI. ANNEXES

Annex 1. Control of diseases in Integrated Apple Tree Production

Disease	Times of treatments and comments
Bark canker and fruit tree cancer	Spray immediately after spring crown has formed, after deleafing in nurseries and in case of any bark damage (e.g. due to hail). Protect large wounds after pruning trees with preparations in the form of paste.
Fire blight	Chemical control should start when orchards where the disease occurred and orchards close to fire blight outbreaks are in the bud swelling stage. If there is high risk of infection during fruitlet growth, 2-3 sprayings should be carried out every two weeks. Also protect tree rootstocks susceptible to fire blight. When the fruitlets fall in June, spray only in case of a strong infestation, especially after hail.
Apple scab	Apply preventive treatments from the moment ascospores are released until the end of primary infections. Apply preventive treatments based on signalling when there is a high risk of infection. Apply further protective treatments depending on the results of the inspection. The most important period in the control of apple scab starts from the stage of visible flower buds.
Apple powdery mildew	In spring, remove all infected shoots with signs of disease. Chemical control should start during the pink bud stage when more than 4 % of the shoots are infected. If the severity of the disease in the orchard is low, the chemical treatment should be completed at the end of June. If, at the end of June, the disease intensity exceeds 30-40% of the infested shoots, chemical protection should continue.
Grey mould	Apply fungicide treatments once when flower petals fall or twice, in full bloom and when flower petals fall. Fungicides applied in the pre-harvest period also protect against disease during storage.
Brown rot	Chemical control of apple scab in the first half of the summer also protects fruit from brown rot. In the second half of the season, 2-3 more treatments should be applied, especially on susceptible varieties and when there is a high risk of disease.
Bull’s eye rot	Start treatments 1.5-1 month before harvesting apples. Spray one to three times depending on the severity of the disease in the previous year, the susceptibility of the variety and the weather conditions. Rotate fungicides and respect the grace period.
Collar rot	At the end of flowering time, apply approximately 0.5 l of spray liquid per tree to the base of the trunk and the soil around the trunk. Repeat the treatment after one month.

Annex 2. Risk thresholds for major apple tree pests

1	2	3	4
Name of pest	**Time of inspection**	**Inspection method and sample**	**Risk threshold**

1	2	3	4
		size per approx. 5 ha	
1	**2**	**3**	**4**
Grubs (before the orchard is started)	from May to the end of August	take soil samples from 32 wells, dimensions: 25 cm x 25 cm, depth 30 cm, area 2 m^2, check for the presence of grubs	One grub per 2 m^2 of the field area
European red mite	leafless tree period	inspect one 2-3-year-old branch from 40 trees, check for the presence of winter eggs of the European red mite	5-degree scale[1]: 0 and 1 – do not control before flowering, 2 – perform inspection in the pink bud phase, 3 and 4 – treatment necessary before flowering (only applicable to the European red mite)
European red mite and red spider mite	pink bud stage	inspect 1 leaf flower rosette in the middle of the crown from 40 trees (approx. 200 leaves in total), check for the presence of moving forms of spider mites	on average, three or more mobile stages (larvae and adults) per 1 leaf
	end of flowering	and then every 10-14 days inspect after 1 leaf flower rosette in the middle of the crown of 40 trees (approx. 200 leaves in total)	as above
	second half of July and later	every 10-14 days, inspect 5 leaves from a tree, from the outer part of the crown from 40 trees (approx. 200 leaves in total)	on average 5 and more moving forms of spider mites per leaf, (**red spider mite** is controlled at a lower threshold – **3 individuals/leaf**)
Apple rust mite	leafless period – stage 1 (professional method)	take a one-year-old shoot from each of 20 randomly selected trees. On each one, inspect 10 buds (check 5 buds from the top first), or	an average of 20 individuals per 1 bud or
		inspect one two-year shoot on 20 randomly selected trees	average 50 individuals per 10 cm of current shoot
	beginning of pink flower budding	inspect at least one rosette from 10 randomly selected trees of each variety	an average of 50 individuals per rosette
	from mid-June to mid-August	every 2 weeks review 10 leaves from 20 trees (by mid-July take leaves from the middle of the rosette or long shoots, later from the top), count	20 to 40 individuals per 1 cm^2 of leaf

1	2	3	4
		eriophyoidea on the bottom side of the leaf, at its base, around the main nerve, on the surface of approx. 1 cm^2	
Apple blossom weevil[2]	leaf-free period (stage 2)	inspect 10 buds on short shoots from 40 trees (400 buds in total) for damage	60 buds with traces of beetle damage in a sample of 400 buds
		shake the beetles from 35 randomly selected trees (1 branch per tree) into an 0.4 m × 0.6 m entomological umbrella (sheet)	5-10 beetles from 35 branches, depending on the expected flowering intensity
Leaf-rolling caterpillars; other caterpillar species	green bud (stage 4)	inspect 10 leaf-flowered rosettes from 20 trees (200 in total) for the presence of caterpillars	3-5 caterpillars of moths in a sample of 100 rosettes
	pink bud (stage 5)	as above	as above
	from mid-June to mid-September, every 2 weeks	inspect 20 shoots from 20 trees (400 in total) for the presence of caterpillars	2-3 % of shoots infested with caterpillars in a sample of 400 shoots
		inspect 20 fruits from each of 20 trees (400 in total) for signs of damage; at the same time, record any damage caused by the apple fruit moth	1-2 % (4-8 pieces) of fruit with fresh damage in a sample of 400 fruits
	from mid-August to fruit harvest, every 2 weeks	inspect 20 leaves and 20 fruits from 20 trees (400 leaves and 400 fruits in total) for damage	4 caterpillars/400 leaves or 4-8 fruits damaged in a sample of 400 fruits
Bud moth[3]	set up pheromone traps in the third week of May; continue monitoring until the end of August	check the traps 1-2 times a week, record the number of moths and remove them from the trap	a dozen or more moths caught in a week within 1 trap
Dark fruit-tree tortrix[3]	set up pheromone traps in the third week of May; continue monitoring until the end of September	check the traps 1-2 times a week, record the number of moths and remove them from the trap	7-10 moths caught in a week within 1 trap
Cherry-bark moth[3]	set up pheromone traps in the second week of May; continue monitoring until the end of	check the traps 2 times a week, record the number of moths and remove them from the trap	a dozen or more moths caught in a week within 1 trap

1	2	3	4
	August		
Summer fruit tortrix[3]	set up pheromone traps in the second week of May; continue monitoring until the half of August	check the traps 2-3 times a week, record the number of moths and remove them from the trap	a dozen or more moths caught in a week within 1 trap
Rose tortrix[3]	set up pheromone traps in the 2nd half of June or the 1st half of July	check the traps 2-3 times a week	the presence of moths in the trap means that control will be necessary **in spring of the following year**
Apple sawfly	period of pink flower bud until the end of flowering	before flowering, hang white sticky traps to catch adult apple sawflys, check every two days	on average, 20 individuals per 1 trap in the period from the pink bud to the end of flowering
Woolly aphid	before and after flowering, and thereafter systematically every 1-2 weeks	inspect trunks, branches and root suckers of 50 trees	2 trees with colonies of live aphids in a sample of 50 trees
Aphids	emergence of the first leaves	inspect 20 buds from 10 trees (200 buds in total)	10 buds with aphids in a sample of 200 buds, and if there is only apple-grass aphid, control is necessary when more than 100 buds are inhabited in a sample of 200 buds
Apple–plantain aphid	after flowering and thereafter every 2 weeks till mid-July	inspect foliage of 50 randomly selected trees	one tree with aphid colonies in a sample of 50 trees
Green apple aphid	after flowering	inspect 3 long shoots on 50 randomly selected trees (150 long shoots in total)	15 shoots with aphid colonies in a sample of 150 shoots
	end of June and later	as above	as above
Apple psyllid	when larvae hatch, usually at the beginning of the green bud stage	inspect 10 buds or rosettes from 20 trees (200 in total) for the presence of psylloidea larvae	60 rosettes with an apple sucker in a sample of 200 rosettes
Pear leaf miner	from mid to end of June	inspect 40 leaves on 10 trees (400 in total) for the presence of the pear leaf miner	40 miners per 400 leaves, control when the second generation of adults fly
	end of August	inspect 40 leaves on 10 trees (400 in total) for the presence of the pear leaf miner	400 miners per 400 leaves, control necessary in spring the following year

1	2	3	4
Banded apple pygmy	from mid to end of June	inspect 40 leaves on 10 trees (total 400) for the presence of the apple pygmy	80-100 miners per 400 leaves, control when the second generation of adults fly
	end of August	inspect 40 leaves on 10 trees (total 400) for the presence of the apple pygmy	800-1 000 miners per 400 leaves, control necessary in spring of the following year
Red-belted clearwing	hang pheromone traps in the third decade of May; observations are made until the beginning of August	check the traps 2-3 times a week	a dozen or more moths caught in one trap within a week
Codling moth	hang pheromone traps at the beginning of May – monitor until mid-August	check the traps 2-3 times a week, record the number of moths and remove them from the trap	presence of moths (average 5 and more per day) in the trap over 3-4 consecutive days
	beginning of June and then every 1-2 weeks until the end of August	inspect 20 buds or fruits on 25 trees (500 buds or fruits in total)	10 eggs or fresh bites in a sample of 500 fruitlets
	harvesting period	inspect 1 000 fruits	10 damaged fruits (1%), control the following year
Vapourer moth	Leafless tree period	inspect crowns of 50 trees for eggs	if deposited eggs are found, carry out an inspection in the pink bud stage
	pink bud stage	inspect 5 leaf-flower rosettes in the middle of the crown of 40 trees (200 in total) for the presence of caterpillars	four caterpillars in a sample of 200 rosettes
	end of July, the first half of August	inspect foliage of 50 randomly selected trees	2-3 trees with caterpillars on them
Common vole	late autumn	inspect at least five rows of 100 m in length in each plot	at least a dozen or so active colonies per hectare of orchard
European water vole	after harvesting (October, November)	inspect at least five rows of 100 m in length in each plot	at least a dozen or so active colonies per hectare of orchard

[1] Spider mite eggs on the shoots:
0 – eggs are not present,
1 – very small (hard to notice, single eggs),
2 – moderate (groups of eggs, approx. 0.5 cm in diameter),
3 – strong (groups of eggs, 0.5 cm to 1 cm in diameter),
4 – very strong (red spots, over 1 cm in diameter).

[2] Inspect for the presence of the flower borer and damage on a sunny day with temperatures above 10 °C, in areas of greatest risk in the vicinity of woodland, hedgerows and scrub.

[3] The flight of moths of different species of tortrix moths can be tracked using pheromone traps.

Annex 3. List of pests and time of pest control

Pest	Times of treatments and comments
Apple blossom weevil	Before buds break and when buds start to break. Spray at a temperature of at least 12 °C.
Apple sucker Hawthorn sucker Summer apple sucker	Treatment should be carried out when a risk threshold is exceeded (just after the buds break or at the beginning of the green bud stage). Controlled simultaneously with apple sucker.
Leafroller moths	In spring, carry out the treatment in the green bud period or at the beginning of the pink bud period. In summer, control larvae during the hatching period. Vary the dates of control depending on the species present in the orchard. To determine the dates of control treatments in summer, moth emergence should be monitored based on catching males in pheromone traps.
Winter moth	Treatment should be applied after all caterpillars have hatched, in the pink bud stage, when a risk threshold is exceeded.
Apple fruit	Control at the beginning of larval hatching, by the time petals fall if a risk threshold is exceeded.
Codling moth	To record the flight dynamics of moths, use pheromone traps and hang them in the orchard at the beginning of May. To determine treatment dates, the mode of action of the product on the pest should be taken into account. Insecticides against eggs should be used during intensive (stabilised) moth flights and egg laying. Codling moth adults are active during warm days, evenings and nights (at temperatures above 15 °C). Treatments effective for hatching caterpillars should be applied a few days later, during the black head stage of the codling moth egg. Depending on the pest intensity, 2-3 sprayings should be made (1-2 treatments against the first and 1 treatment against the second generation of codling moth).
Green apple aphid and the apple–plantain aphid	Spray when the pests are observed.
Apple ermine moth	Control when larvae start to emerge on leaves (usually at the beginning of the pink bud stage).
Apple mussel scale	Control at the time of larvae hatching, usually during the flowering period of hawthorn.
Apple rust mite	Treatment after flowering.
Spider mites	Control when a risk threshold is exceeded. When selecting a product, take into account the developmental stages of the pest that the product is intended to control.

Woolly aphid	Control when the pests are observed. Repeat the treatment after about two weeks.
Pear leaf miner Banded apple pygmy	Treatment should be applied at the time of larvae hatching, by the time flower petals of winter apple varieties fall. If you have a heavy infestation, repeat spraying after 7-10 days.
Apple-blister mite	Control in orchards that are at risk, after Eriophyoidea emerge from buds, before flowering.
Apple leaf midge	Control after flowering when the first damaged leaves are observed.
Vapourer moth	Control when caterpillars are observed.
Maybeetle	Eradicate in endangered orchards when beetles invade.
Bracken clock	Eradicate in endangered orchards when beetles invade.
Tooth-nosed snout weevils	Eradicate in endangered orchards when beetles invade.
San Jose scale	Immediately after detection of the pest.
Apple mealybug	Immediately after detection of the pest, it is usually destroyed during control of other pests, e.g. woolly aphid.
Larger shothole borer Shothole borer Pear blight beetle	Immediately after detection of the pest. The number of borers may be reduced by chemical treatments performed against other pests.
Goat moth Leopard moth	During the flight of moths as there is no chemical control of caterpillars.
Red-belted clearwing	During the flight of moths.
Dock sawfly	After seeing the first damaged apples.
Common vole European water vole	Use poisoned bait after harvest (October, November).
Game (hares, roe deer, deer, elk)	Upon noticing the first damaged trees.