NATIONAL UNIVERSITY OF LIFE AND
ENVIRONMENTAL SCIENCES OF UKRAINE

EDUCATION AND RESEARCH INSTITUTE OF
FORESTRY AND LANDSCAPE-PARK MANAGEMENT

PEST MANAGEMENT IN FORESTS OF EASTERN EUROPE

MANUAL

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Навчальний посібник розкриває екологію шкідливих організмів лісових екосистем та причини порушення нормального стану лісів. Також розглянуто методи попередження виникнення та поширення, боротьби з шкідниками в лісі. Зміст навчального посібника відповідає навчальній програмі дисципліни «Pest management in forests of Eastern Europe». Посібник буде корисний студентам, аспірантам, докторантам, викладачам закладів вищої освіти, спеціалістам лісового господарства та лісозахисту.

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Навчальне посібник

PEST MANAGEMENT IN FORESTS
OF EASTERN EUROPE

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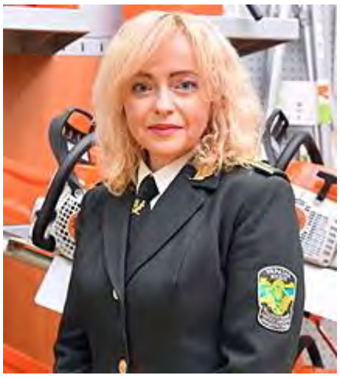

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CONTENS

INTRODUCTION

Forests provide ecological, economic, and social many functions.

However, to obtain the wood, the forester must control the organisms that are harmful to tree growth. About 3% of Europe’s forests are affected by damage caused by both biotic and abiotic factors. The damaging agents include wildlife and grazing, insects and diseases, forest fires, storms, wind, drought and snow.

Abiotic damage contributes to the increase in biotic damage through the deterioration of tree condition and the increase in their susceptibility to pests. Biotic damage may also increase the sensitivity of forests to abiotic damage.

Insects, pathogens and other pests have considerable impacts on forests. They can adversely affect tree growth and the yield of wood and non-wood products. Damage caused by forest pests can significantly reduce wildlife habitat thereby reducing local biodiversity and species richness. They can change natural forest landscapes by destroying one or more tree species. Some pests have necessitated modifications in management regimes that force forest managers to switch to alternative tree species in stands. Pathogens may also limit the areas on which species can be grown successfully. Insects and diseases destroy each year more timber than other damaging causes. Some of such losses are a part of the natural cycle in the forest. However, forest can decline if these natural processes are thrown out of balance.

The value of forest consists in a wide variety of resources. Various forest pests can threaten these resources. Therefore, it is important to monitor forest health and meddle when those resources are at risk. The proper forest management, early detection of pests, and correct protective measures can prevent or reduce the effects of pest problems. In addition, it should be available more intensive management and control options.

Forest pest management can be difficult for some reasons. It does not be possible the cost-intensive control options that are utilized for agricultural crops. Complete control or eradication of forest pests is often difficult or impossible to achieve. Trees are grown on huge acreages that makes monitoring difficult, access problematic, and management of pests very expensive. Trees have a long-lived time and exposed too many stress agents over their lifetime. Trees are very large organisms, so close examination of a total tree is impossible.

Chemical treatment also can not be used on a vast territory. Any chemical measures or control options may adversely affect other nearest organisms. Therefore, forest managers must use an Integrated Pest Management approach when dealing with forest pests.

Chemical protection is regulated in the European Union (EU). The XX century Directive 91/414 of the 1990s influenced the availability of active substances in the EU, while Directive, 2009/128, which limited aerial spraying and introduced obligatory implementation of integrated pest management by all professional users of pesticides, was enforced in 2009.

The main blocks of the IPM system include:

– forest pathology monitoring;

– accumulation and analysis of information;

– forecast of forest damage and the consequences;

– decision-making;

– operational measures (chemical, biological, etc.);

– preventive (establishment measures);

- control over the consequences of such measures;

– adjustment of forecasting and decision-making blocks.

To these blocks, the structure of this Manual is adopted. At the end of the manual, supplemental information and a glossary are presented.

Terms throughout the manual text are bold and italicized. Latin names of pest species are italicized.

Training manual would be useful to Masters' students, and anyone interested in learning more about forest pest management.

CHAPTER 1
ECOLOGY OF FOREST AND PESTS

1.1. Causes of violation of the normal forest condition

Violation of the normal condition of the forest ecosystem is caused by a variety of causes. They can be combined into three groups of factors (Fig. 1.1): abiotic, biotic and anthropogenic.

Abiotic factors include climate, relief, soil, and reservoirs. They affect directly or indirectly on trees growth and health as well as on pests. The wind can cause windbreak and windfall. Damage to the trunk and branches can be caused by snow. Dry and warm weather contributes to the development of fires, and droughts – the weakening of plants. Forest fires are the most common natural disaster in forests. They have a great negative impact on most forest life processes, including the change of forest formations. Fire damaged stands become the foci of forest pests.

Various changes in the soil (waterlogging, a sharp decrease in groundwater level) also lead to disruption of the normal life of forest ecosystems. As a result, unfavorable abiotic factors bring the attack of pests and mass forest mortality.

Weather conditions (temperature, humidity) as well as day length (photoperiod) affect pest activity and their rate of reproduction.

Biotic factors include all living organisms that are part of the ecosystem. Insects defoliate crowns, which leads to reduced tree growth and other undesirable consequences. Stem pests accelerate the death of weakened trees or entire stands. Settling under the bark, they damage the phloem, wood and cause profound changes in the life of trees. Some insects destroy fruits and seeds. Mammals cause significant damage in forest. Large number of ungulates, especially elk, break plantings, peel the bark, destroy the branches. Parasitic fungi have a great negative impact on forest ecosystems. Root rot causes the death of trees, increases windbreak and windfall, reduces increment. Other fungi, cause stem rot, reduce the yield of commercial wood, promote the development of windbreaks.

Anthropogenic factors are human activities. The impact of human economic activity on the state of forests is extremely diverse. This impact can be positive (silviculture, tending and pest protection) and in some cases negative, when human activities contribute to the gradual degeneration and extinction of plantations, accompanied by the development of dominative pests. We will consider only some of the negative aspects of the impact of human activities, the elimination of which is possible.

Anthropogenic factors cause many pathological processes in the forest. Further growth of technology and population, as well as urbanization create more unexpected effects on forest ecosystems. Under the influence of man in the natural complexes there have been huge changes. Over the centuries, vast tracts of forest have been destroyed, rivers dried up, deserts and moving sands appeared, many animals and plants declined sharply, and some of them have disappeared.

Anthropogenic factors affecting forest health include technogenic pollution, soil contamination with pesticides and other agrochemicals, recreation, fire initiation, cattle grazing, tree and soil damage during tapping, and other kinds of forest management activity, etc.

Soil contamination with pesticides and other agrochemicals. Pesticides can contaminate soil, water, turf, and other vegetation. Chemical care of the forest can cause irreversible changes in biodiversity. In addition to killing insects or weeds, pesticides can be toxic to a host of other organisms. Application of herbicides, insecticides and fungicides negatively affects the populations of beneficial insects, particularly ants, entomophages and pollinators (bees).

Forest recreation. Increasing urbanization and propagation of an active lifestyle have created a demand for outdoor recreation.

Forests also provide areas for biking, orienteering, and other activities. At the same time, forest recreation leads to forest alteration. Forest recreation leads to compacted soils, disturbed organic layers, and excessive rates of soil erosion. Soil compaction restricts root growth, and greatly minimizes the nutrients. Soil compaction also reduces water and oxygen available to vegetation. It has a significant detrimental effect on soil microorganisms. The loss of organic substances affects mycorrhizal fungi, which are very important to many tree species.

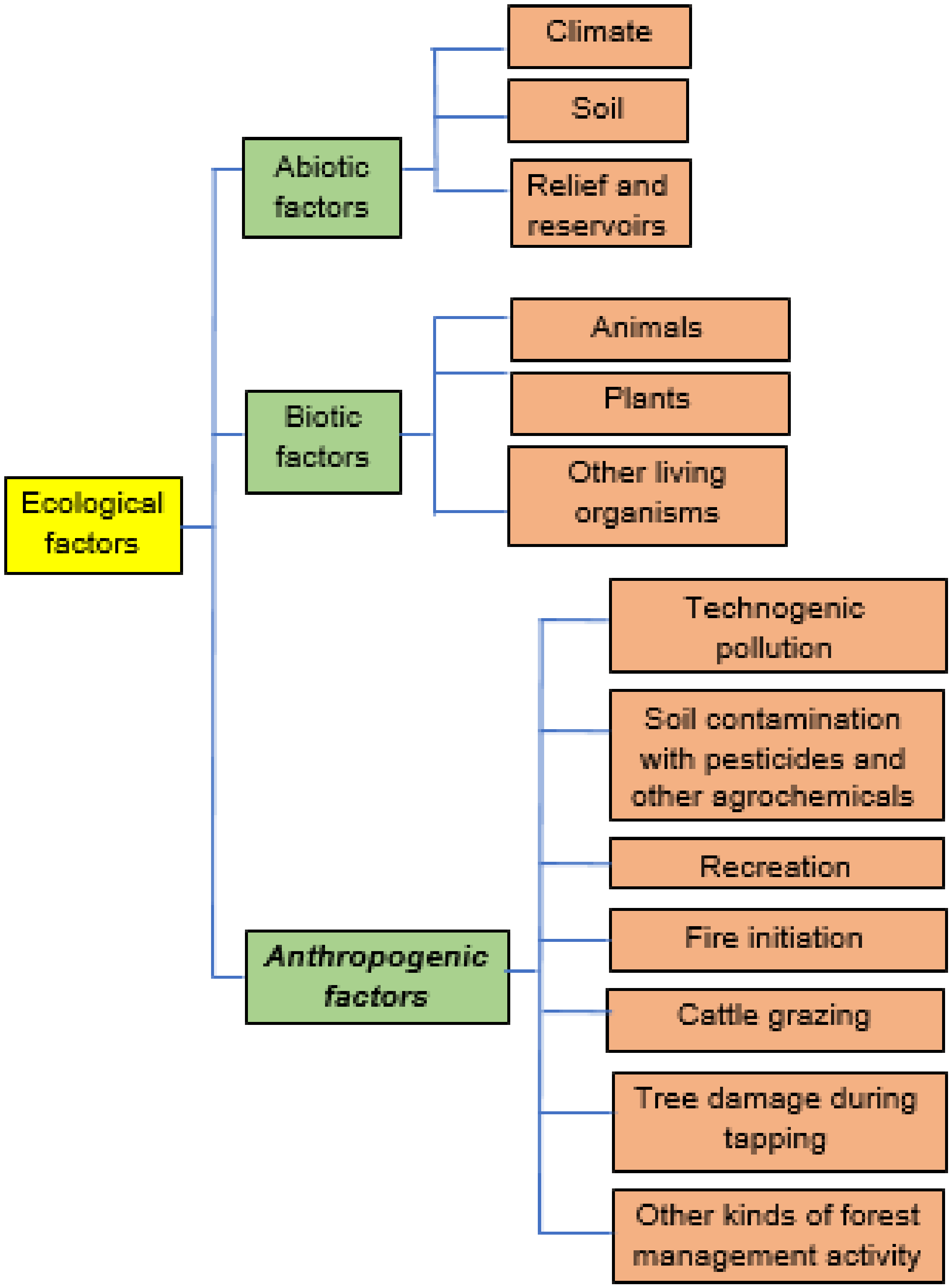

Fig. 1.1. Main ecological factors

All the above human activity leads to opening new gate for hit of different pests, especially pathogens and insects. Disturbed soils also promote the establishment of invasive plant species.

Fire initiation. Nearly 95 % of forest fires are caused by humans. Forest fires result from campfires left unattended, the burning of felling residues, field stubble, use of malfunctioned equipment, negligently discarded cigarettes, and intentional acts of arson.

Cattle grazing. Excessive grazing has a negative impact on forest ecosystem and young forest crops. Cattle grazing leads to worse soil aeration and a water mode, on steep slopes causes soil erosion, on sands it can appear dust storms. Cattle grazing cause weak forests due to the deterioration of the physical properties of the soil.

Tapping in the forest. The tapping of pine is not dangerous if do it according to appropriate rules. In case of violation of tapping technology, it leads to death of individual trees or even stands. When tapping is carried out in the diseased stands, the spread of stem pests increases.

Logging damage. Logging operations alter the natural structure of a forest. Logging increases the likelihood of the introduction and spread of tree insects and diseases. Stumps and felling residues left behind after logging operations become colonized by xylophagous insects or infected by fungi. Trees that are stressed by diseases are more susceptible to attack by insects in particular bark beetles. Young trees may be bent, broken during felling, or crushed by harvesting equipment. Branches and tops of left trees may be broken during felling. Trunks may be wounded, allowing entry of pathogens or insects that cause wood discoloration and decay. Root damage allows entry of rot-causing fungi. Logging may also combine with other stress factors in the forest. The trees with low vigor are attractive to pests.

Monoculture. The biological stability of stands depends on their tree composition. The ecology of mixed plantations is very different from the ecology of pure plantations. Mixed forests make better use of their environment (climate, soil, sunlight, and nutrients). The diversity of the structure allows much fuller use of environmental conditions. Mixed stands are usually more stable. There is never a sharp dominance of one species over another in mixed forests. This fully applies to entomofauna and pathogens. Therefore, the foci of pests rarely occur in rich biodiversity forests. Pure forests can be the foci of insects and pathogens.

Changes in the forest biogeocenosis happen from the very beginning of the impact on it to the complete internal transformation. These changes are called digression. There are five stages of forest digression:

Stage 1 – human activity has not made significant changes in the forest biogeocenosis.

Stage 2 – there are some changes in the forest biogeocenosis: there are paths around which the forest floor is destroyed and the soil is compacted, light-loving plants appear; reforestation is normal.

Stage 3 – soil compaction and forest floor destruction continue, its power is significantly reduced, meadow grasses and weeds predominate; there aren't reforestation on trails.

Stage 4 – a dense grid of paths is formed; forest species are disappearing, the undergrowth is most often absent or curtains of elderberry, raspberry, herbaceous plants are preserved; there are no seedlings, the forest floor is found only in some spots near the base of tree trunks; soil erosion begins.

Stage 5 – forest biogeocenosis acquires a completely different look; forest floor, undergrowth, seedling, and typical forest herbal plants are absent; the soil is strongly compacted, an erosion develops in places of slopes; many trees with dry tops appear, the forest canopy becomes sparse.

It is necessary to closely monitor the stages of digression and timely intervene in the life of the forest to prevent its irreversibility in the 3rd stage. The limit of a qualitative change in the process of degression from reverse to irreversible is called the limit of stability of the forest biogeocenosis. It depends on the nature of the biogeocenosis, its load. From stage 1 to 4 forest biogeocenosis can take 2, 5, 10 years. In the digression area, the number of dry branches in the crowns of weakened trees increases sharply, dry-topped trees appear. Superficial roots suffer greatly. Almost all trees bear traces of mechanical damage, which are the gateway to infections for root rot, honey mushroom and other fungal diseases.

1.2. Forest pests

Forests are complex ecosystems that provide a variety of valuable products, such as timber, fuelwood, non-wood forest products, that contribute to the livelihoods of rural communities. Forests also provide vital ecosystem services, such as combating desertification, protecting watersheds, maintaining biodiversity, deposit of carbon sequestration and play an important role in preserving social and cultural values. It is critically important to protect forest resources from disturbances such as fire, pollution, invasive species, insects and diseases.

While pests are integral components of forest ecosystems, they have considerable influence on the health of forests and plants outside the forests. The pests can adversely affect forest plants survival, growth and vigor, the yield and quality of wood and non-wood products, wildlife habitats, human recreation, aesthetics and cultural values.

Pest management should be aimed that the risks and impacts of unwanted disturbances are minimized. Measures to protect forests from pests are an integral part of sustainable forest use. Effective pest management in forest requires reliable information about the pests, their biology, ecology, and distribution, their impacts on natural ecosystems and possible methods of control.

Plant protection is a set of measures aimed at preventing the deterioration of woody, perennial and other plants due to pests.

Pests, in forestry, mean living organisms that damage plants, destroy food, etc. Forest pests are biotic disturbances, meaning that the source of illness to a tree or to a forest is a living organism. For an understanding description, all pests have been classified into categories. Pests include (Fig. 1.2): weeds, insects, pathogens, rodents, and nematodes.

Weeds are unwanted vegetation in forests, nurseries, which compete with target forest plants for light, water, nutrients, as well as contributes to the spread of some pests.

Insects. They represent the wider portion of forest pests and make up the largest class of phylum *Arthropoda*. Insects have segmented bodies and legs, and exoskeletons.

Pathogens – the organisms that disorder normal metabolism in plants. The pathogens that cause ***diseases*** in forests fall into three main groups: ***viruses***, ***bacteria***, ***fungi***.

***Virus** is small in size and simple in composition. Viruses are intracellular pathogenic particles that may infect other living organisms. They are infectious agents and can multiply only in living organism cells (animals, plants, or bacteria).*

***Bacteria** are single-celled prokaryotic organisms. They do not have a defined nucleus, reproduce asexually by binary fission when one cell splits into two.*

***Bacteria** can multiply quickly. They can multiply quickly. Some factors that lead to infection include high humidity, poor air circulation, plant stress, over-watering, under-watering, irregular watering, deficient or excess nutrients in the soil.*

Fungi. Most plant diseases (about 85 %) are caused by fungal organisms. Kingdom of Fungi includes more than 100 thousand species. A characteristic of fungi is chitin in their cell walls. Fungi are heterotrophs. Fungi do not photosynthesize.

Rodents are mammals of the order *Rodentia* which have specialized teeth for gnawing.

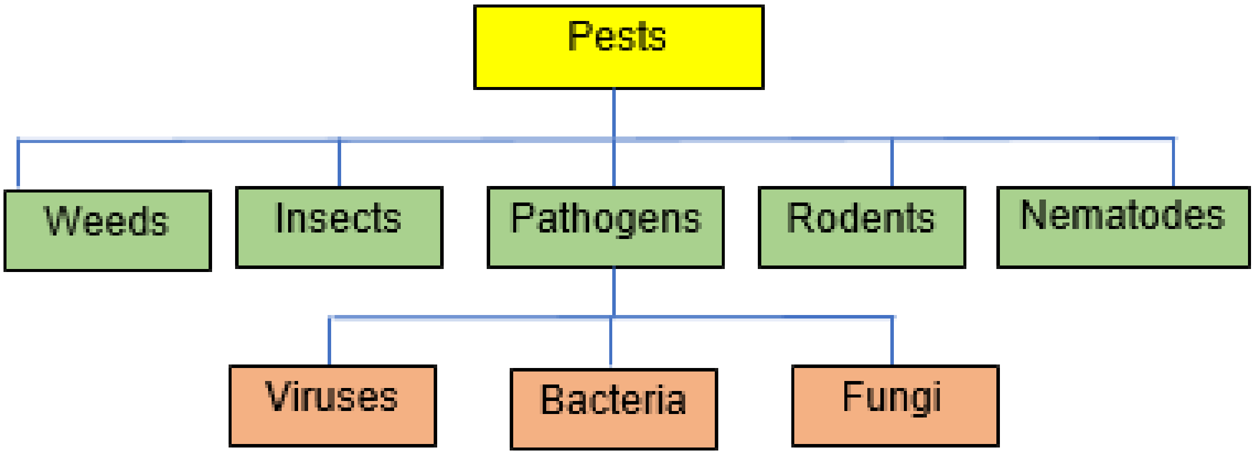

Fig. 1.2. Groups of pests in forests

Nematodes are roundworms.

Other forest pests are represented by slugs, snails, mites, spiders, mammals, birds, etc. There are more insect pests than other pest types in the world. Less part of the pest species are pathogens, and the least part are other pests (rodents, mammals, slugs, etc.). Insects can be easier to recognize and trap than other pests. The impacts of pathogenic diseases on trees are often subtle and difficult to detect. The impacts of infectious diseases on trees are often subtle and difficult to detect and identify the causative agent. Sometimes the impacts of other pests such as nematodes, mammals and parasitic plants on trees are not easy to detect. Almost 62 % of forest pests are recorded in broadleaf forests, over 30 % in conifer forests.

1.3. Parts of plants affected or damaged by pests

A tree consists of the next parts: roots, trunk, bark, branches, shoots, crown, leaves, needles, periodically flowers and fruits. Each part of a tree has a specific function. Such parts of a tree as leave, needles, heartwood, bark, roots, fruits, cones, seeds can be damaged by pests (Fig. 1.3).

Foliage is a plant organ. The leaves and the needles contain chlorophyll which takes part in photosynthesis. During photosynthesis, leaves use energy from the sun to transform carbon dioxide from the atmosphere, water, soil into sugar and oxygen. The sugar is either used or stored in the branches, trunk, and roots. The oxygen is released into the atmosphere.

Trunk (stem) *supports the leaves, and the branches. It contains the xylem, the cambium, the phloem, and the heartwood.*

Heartwood is an inner core of a trunk (stem) that supports the tree. With a growing tree, older xylem cells in the center of the trunk become inactive and die. In such way the heartwood is forming.

Roots soak up vital water and nutrients for trees. The xylem carries water and nutrients to the parts of the tree. In addition, roots help to support the tree as it grows.

Reproductive plant parts produce seeds, fruits, cones.

Fruits, cones, seeds are continuing the growth of the plants. In botanical usage, fruits also include nuts, pods, and berries. Fruits have acquired extensive food meaning.

Bark is the outermost layer of stems and roots of woody plants. Bark refers to all the tissues outside the vascular cambium. It overlays the wood and consists of the inner bark and the outer bark. Cork cell walls contain a waxy substance, which protects the trunk against water loss, and prevents the penetration of insects, bacteria and fungi.

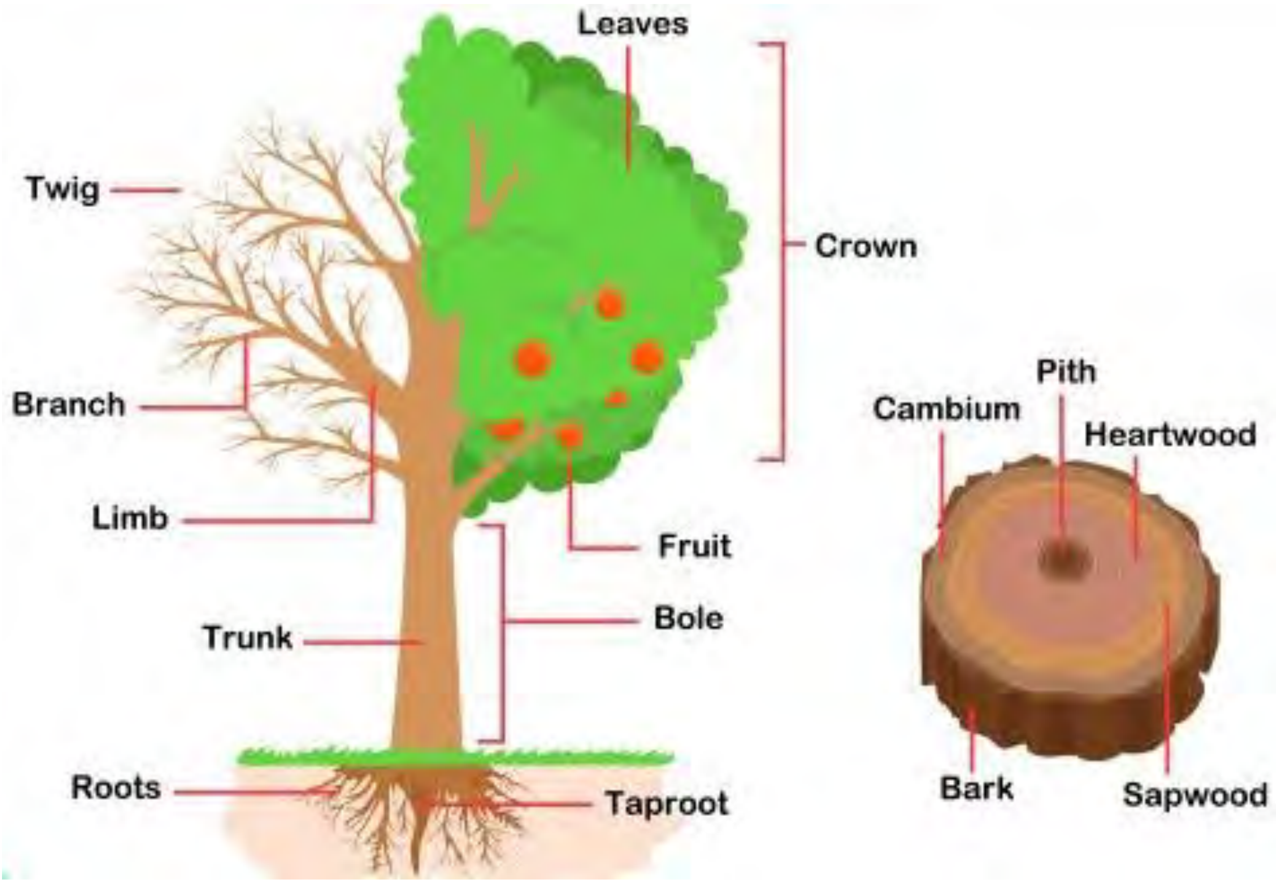

Fig. 1.3. The parts of tree [1]

Locations where pathogens and insects are most likely to enter a tree:

– thin bark areas where limbs meet trunk;

– sunscald damage;

– bird damage;

– broken branches;

– fresh pruning wounds;

– damage by equipment;

– bark lenticels ;

– leaf stomata.

1.4. Interaction between organisms

Organisms live in ecological communities, which are assemblages of populations of at least two different species. They interact directly and indirectly. There are several types of interactions among organisms that are found throughout ecosystems. All interactions between organisms can be divided into (Fig. 1.4): competition, predation, and symbiosis.

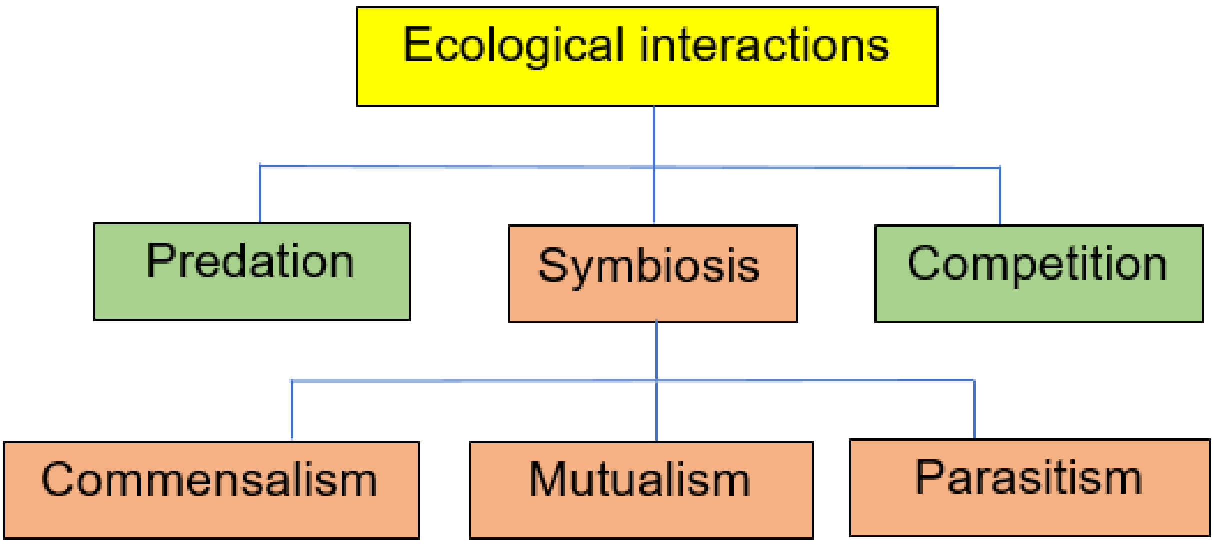

Fig. 1.4. Interaction between organisms

Predation involves one organism (the predator) catching and killing another organism (the prey) for sustenance. You can see examples of predation among the bird population. Sparrows catch insects. Woodpeckers drill holes into tree bark to catch insect larvae.

Competition occurs when two or more organisms rely on the same environmental resource (nutrients, water, territory). Competition among members of the same species is called intraspecific competition, and among different species – interspecific competition. The population of the better-adapted species increases more successfully than the less-adapted species. As an example, larger trees in the forest block sunlight from smaller ones so they cannot grow as well.

Symbiosis is the close relationship between two different species. Such relationships may be harmful, nonharmful, beneficial, or neutral. These interactions typically fall into one of three categories: commensalism, mutualism, and parasitism.

Commensalism is known as a symbiotic relationship where one organism benefits and another does not benefit but is unharmed. A commensal organism obtains food, shelter, moving, or support. Commensalism can be a brief interaction or a lifelong symbiosis. These types of relationships are very common.

Orchids grow on trunks and branches of trees and have their photosynthesis process. They do not harm trees and do not extract nutrients from the host plants. On the other hand, trees gain no benefits from the orchids.

Mutualism is a symbiotic relationship where both organisms benefit from the interaction. Pollination can be a prime example of a mutualistic relationship between plants and insects.

Parasitism is a symbiotic relationship too. Here one organism has benefits itself and has harmed another. There is a host and a parasite in parasitism. The host is a plant or an animal on (or in) which another species lives. Such species living on (in or with) another one for obtaining food is called parasite. Parasites include organisms like mistletoe, which are living in trees. Mistletoe plants its «roots» into the vascular system of the trees, extracting water and nutrients from the host. This can cause significant damage to the tree over time. The next example is a parasitic wasp that lays its eggs on (or in) a caterpillar. Wasp larvae hatch and take nutrition from the living body of the caterpillar.

It is necessary to distinguish between parasites and parasitoids. A parasitoid is an organism that during a significant part of the development period (in the larval stage) lives on the surface or in the body of its only host, which it gradually kills in the course of its development. Imagoes of parasitoids live freely. Unlike parasitoids, parasites do not kill the host.

CHAPTER 2
PHYTOPHAGOUS INSECTS

2.1. General characteristics of insects

Insects inhabit almost all around: terrestrial-aerial areas, soil, water and reservoirs, organisms of other creatures. Forest pests are called ***phytophagous***. They are herbivorous and cause significant damage to plants and wood.

The pest insect orders according to distribution in the world:

Coleoptera 39 %

Lepidoptera 33 %

Hemiptera 17 %

Hymenopters 4 %

Isoptera 4 %

Orthoptera 2 %

Diptera 1 %

Thysanoptera 1 %

To prevent harmful activities of insects, timely limit their populations, organize an appropriate system of measures, experts must know the insect species and identify them, and understand the role of various factors in the development of insect populations and their harmful activities.

The body of insects is divided into three sections: head, thorax and abdomen. The head is covered with a solid cuticle. The body is also covered with a cuticle, which plays the role of the outer skeleton. It protects insects from adverse conditions, prevents water from evaporating, and serves as a place of attachment inside skeletal muscles.

Insects, like other living organisms, are classified using a hierarchical system of classification. The most important taxonomic unit is the species. Species is the group of organisms with similar characteristics. The organisms of same species can reproduce sexually or interbreed and produces fertile offsprings. It is a basic unit of classification and taxonomy. Species is a set of individuals with similar features of body structure, biology, and ecology. They have their own area. Close species unite into a genus, and close genera form a family. The supreme systematic groups are phylum, class and order.

All known insect species are assigned to the appropriate genera, families, and order.

Populations are groups of closely related individuals that create separate settlements.

INSECT TAXONOMY (Fig. 2.1): KINGDOM → PHYLUM → CLASS → ORDER → FAMILY → GENUS → SPECIES.

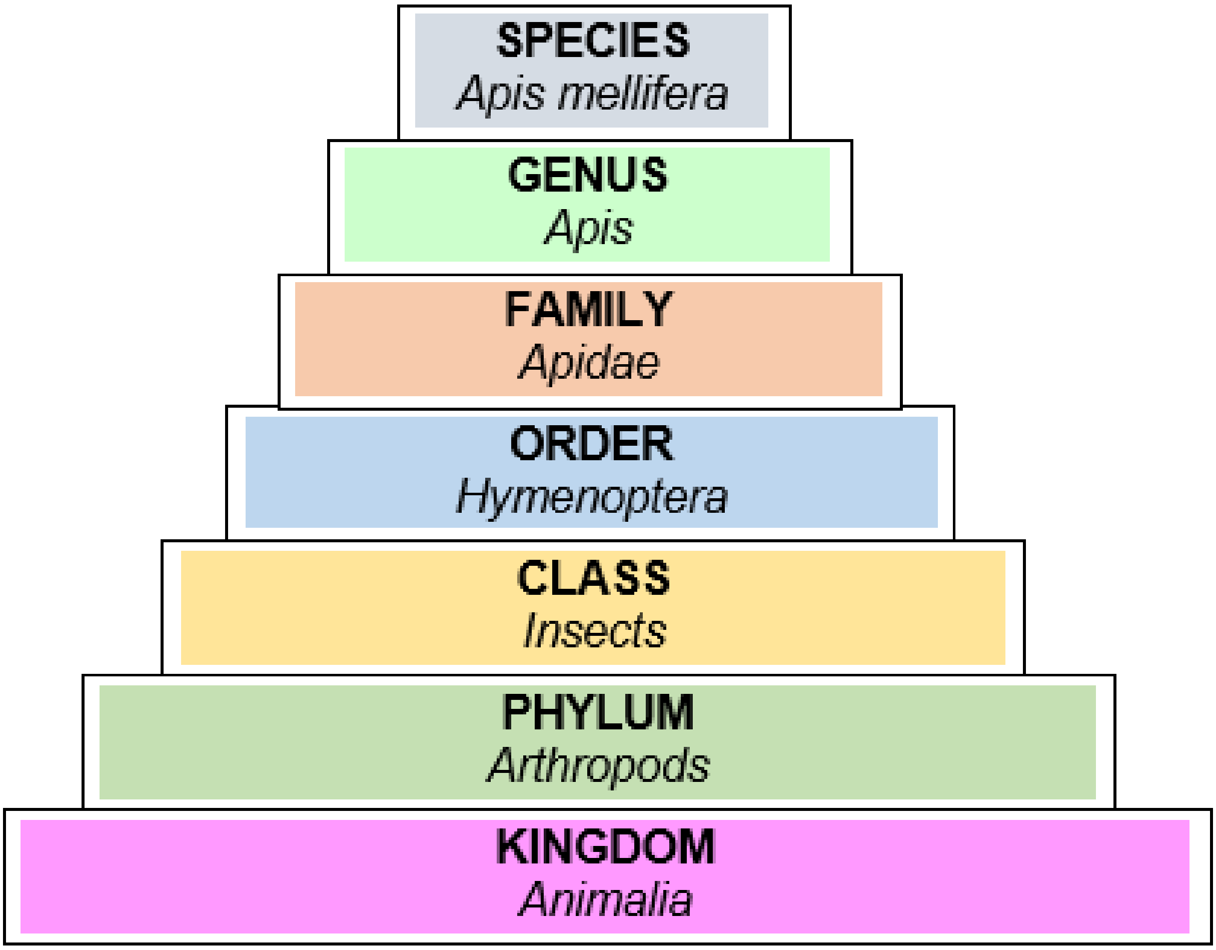

Fig. 2.1. Insect taxonomy (*Apis mellifera* L.)

There are the most common orders of insects that damage forest plants*:* ***Orthoptera, Coleoptera, Trysanoptera, Hemiptera, Lepidoptera, Hymenoptera, Diptera.***

Orthoptera is an order of insects that comprises grasshoppers, crickets, and locusts (Fig. 2.2). Some grasshoppers spread viruses as just mechanical carriers of the infection. Orthopterans have a body adapted for jumping. They range in size from a few millimetres to 30 cm.

Orthoptera have some features. They have two pairs of wings. Their forewings are narrower than their hind wings. They have large composite eyes. Antennae may be short or very long depending on the species. Hind legs are enlarged, that are modified for jumping. Many orthopterans can produce sound.

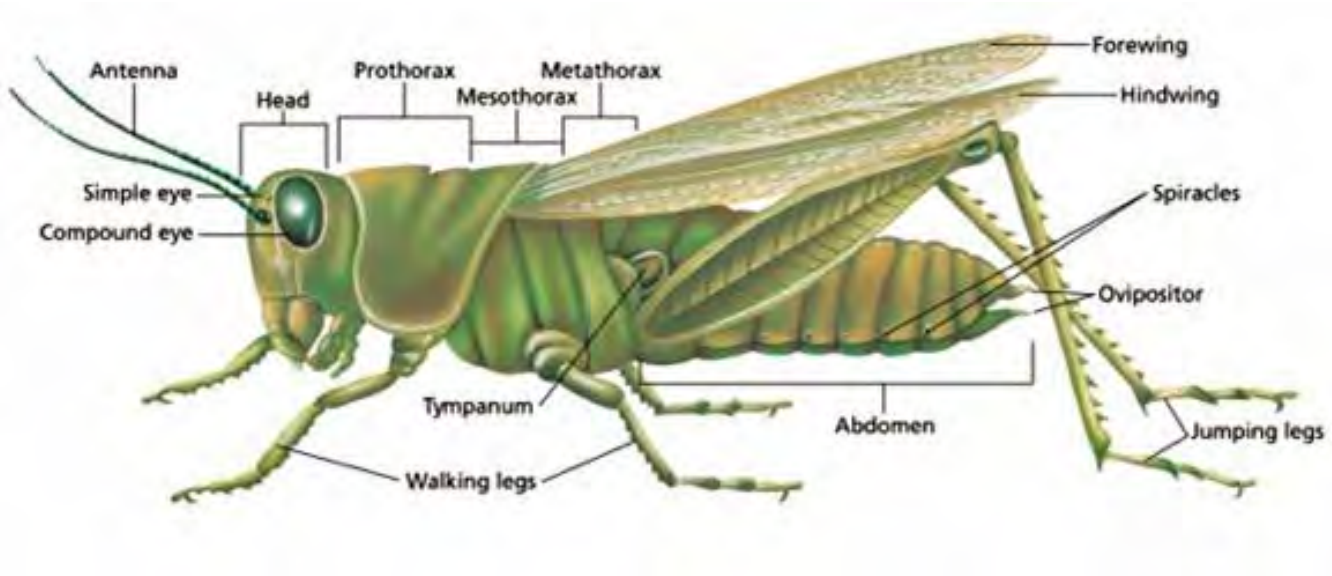

Fig. 2.2. Body structure of *Orthoptera* (grasshopper) [2]

Life Cycle. *Orthoptera* develop by incomplete metamorphosis. Most of orthopterans lay eggs in the ground or on vegetation. When the eggs hatch, the young nymphs resemble adults. However, they have no wings. Through molts (6–10), the nymphs develop wings. Their growth may take anywhere from a few weeks to several months. It depends on food availability and weather conditions.

Feeding. Most *Orthoptera* are herbivorous feeding on plant parts including roots. Some species are predators or necrophagous.

Habitat. Orthopterans are usually found singularly or in small numbers. They inhabit vegetation, from ground level to the canopy or in burrows in the soil.

Coleoptera. This order consists of beetles and weevils (Fig. 2.3). *Coleoptera* is the largest order, representing about 40 % of the known insect species. Beetles come in a variety of shapes and colours and can range 0.4–80 millimeters in length. They have two pairs of wings.

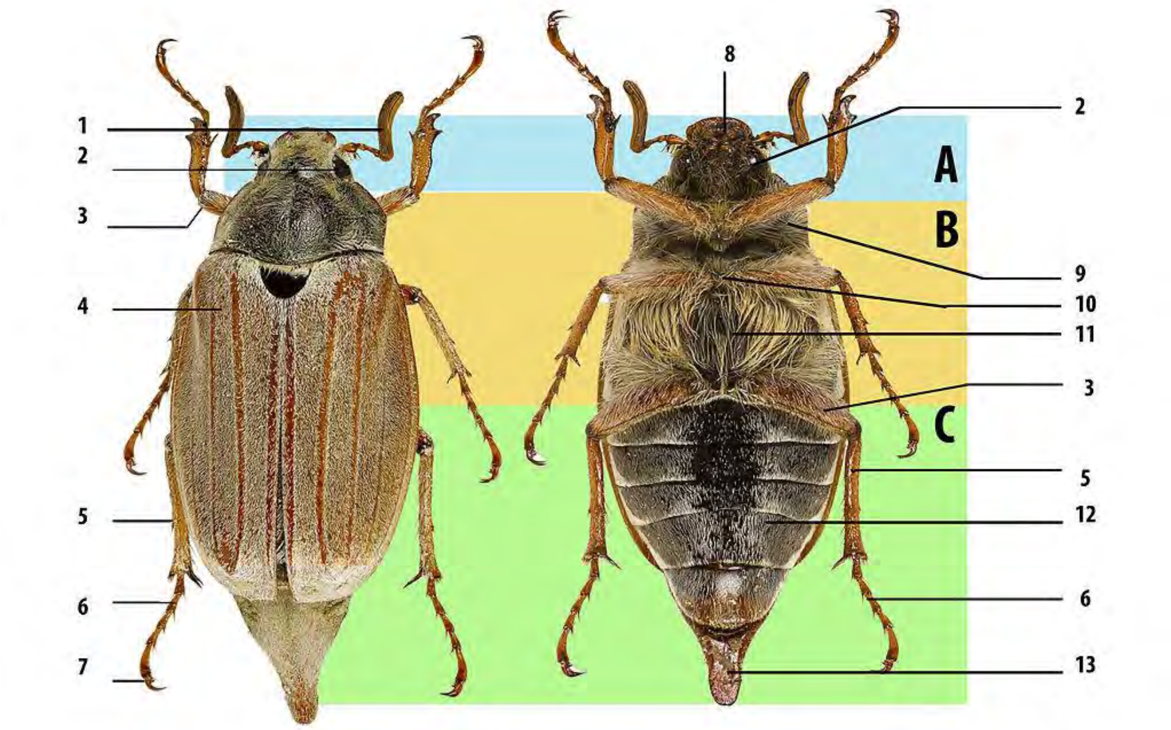

Figure 2.3. Body structure of *Coleoptera* (cockchafer) [3]

A. Head (1. antenna, 2. compound eye, 8. Mouthparts)
B. Thorax (3. femur, 4. elytron, 9. prothorax, 10. mesothorax, 11. metathorax)
C. Abdomen (5. tibia, 6. tarsus, 7. claws, 12. abdominal sternites, 13. Pygidium)

The front pair is modified into horny covers (elytra). *Coleoptera* is the only order of insects that have elytra. They hide another pair of membranous hind wings. Beetles have chewing mouthparts.

They attack the roots and stems around their base, after which the plants wither and often die.

Life cycle. *Coleoptera* have a complete life cycle, their development can take anywhere from a few weeks to several years. They usually lay eggs on or near the food source.

Feeding. Beetles are usually herbivores, predators of other invertebrates (*Carabidae*) or necrophagous. Some adults do not feed at all. The most abundant are plant seed-eaters (*Curculionidae*), nectar feeders (*Buprestidae*), foliage eaters (*Chrysomelidae*), timber beetles (*Cerambycidae*) or bark beetles (*Scolytinae*). Others may feed on dead animals (*Silphidae*), and rotting wood (*Lucanidae*).

The feeding habits between larvae (Fig. 2.4) and adults (Fig. 2.5) can vary. Some beetle species are predatory in the larval stage and plant-feeders in the imago stage.

Fig. 2.4. *Scolytus mali* Bechst. (Larva)

Fig. 2.5. *Scolytus mali* Bechst. (Imago)

Habitat. Most are terrestrial that can be found living in soil, humus, and leaf litter, under the bark of dead or living trees, in decomposing wood, the fruiting bodies of fungi.

Trysanoptera are minute (up to 1 mm long), slender insects with fringed wings and unique mouthparts (Fig. 2.6). *Thysanoptera* is divided into suborders: *Terebrantia* and *Tubulifera*.

Different species of *Trysanoptera* (thrips) feed mostly on plants. They puncture and suck up the contents. Some of them are predators. They fly only weakly. Flight-capable species have two similar wings with a fringe. They have composite or simple eyes. Mouthparts are asymmetric.

Some species transport more than 20 viruses that cause plant diseases. Some *Trysanoptera* species are beneficial as pollinators or as predators of other insects or mites.

Feeding. They prefer tender parts of the plant: buds, flowers and new leaves. Some of them are important members of the ecosystem, in their diet often includes pollen. Other species form plant galls. The third ones are predatory on mites and other thrips. They may feed on the eggs of the hosts and are considered beneficial in pest management.

Habitat. These live among leaf litter, on dead wood. Some Trysanoptera cause galls of leaf tissue and live there. Galls may occur as rolls, folds, alterations, distortion to leaf blades, and petioles. Some species invade stems, creating long-lasting woody galls.

Hemiptera are extremely diverse in their size, shape, and colour (Fig. 2.7, 2.8). They have two pairs of wings, but some species may be wingless or have only forewings. Their mouthparts are piercing or sucking known as a proboscis. Their eyes are composite, in various forms. Antennae may be short or long.

The young *Hemiptera* look like small adults. This order is divided into three suborders: true bugs (*Heteroptera*), hoppers (*Auchenorrhyncha*), aphids, mealy bugs, and scale insects (*Sternorrhyncha*). Aphids, scales, and mealy bugs usually have soft bodies. Most species are wingless.

Life Cycle. *Hemiptera* develop by incomplete metamorphosis. The nymphs of cicadas are quite different from the adults. Nymphs molt 6-8 times before they attain maturity.

Feeding. Most species of *Hemiptera* are plant feeders, sucking sap. They feed by puncturing plant or animal tissues. The liquid food is sucked up by the tube of mouthparts.

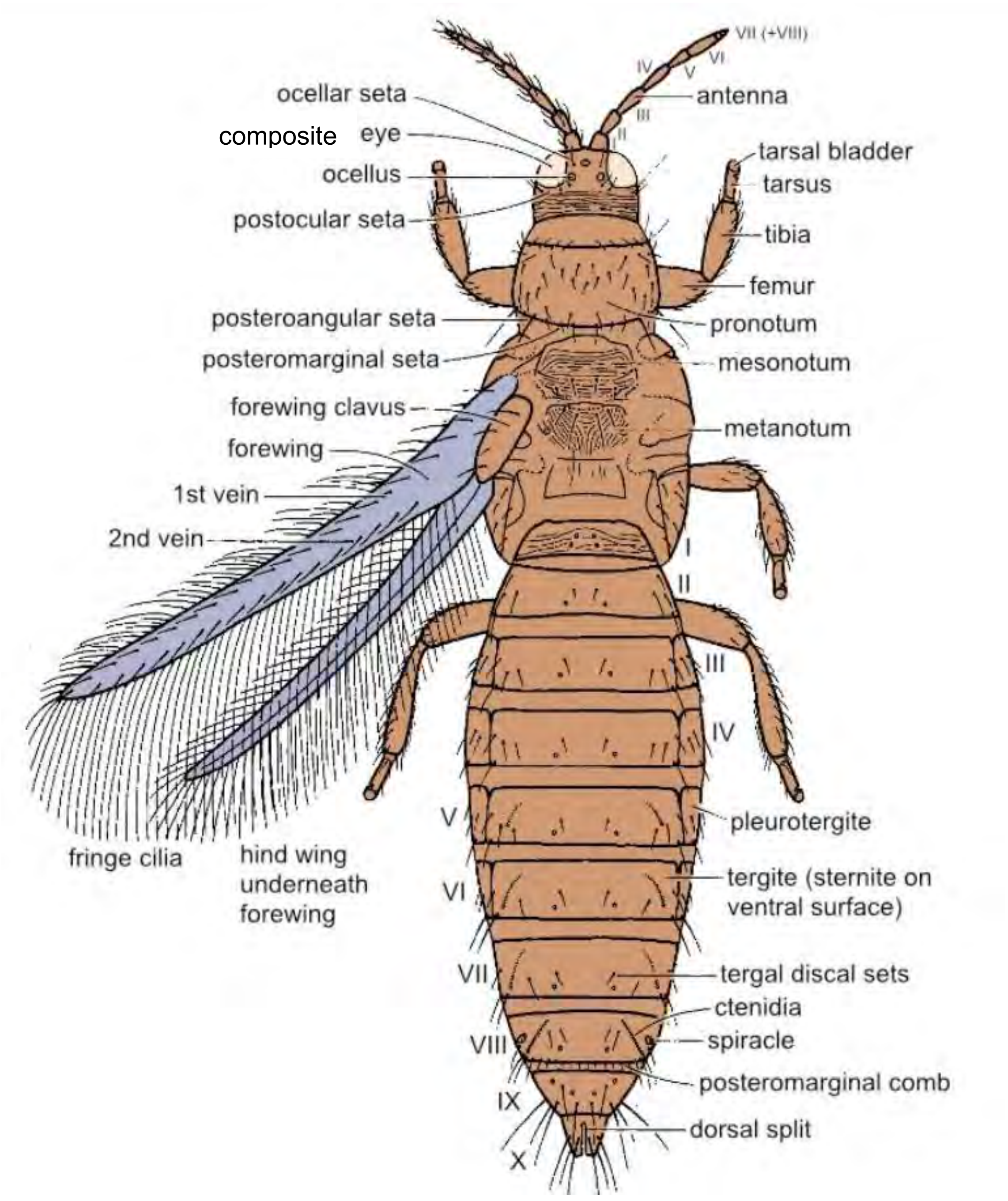

Fig. 2.6. Body structure of *Trysanoptera* [4]

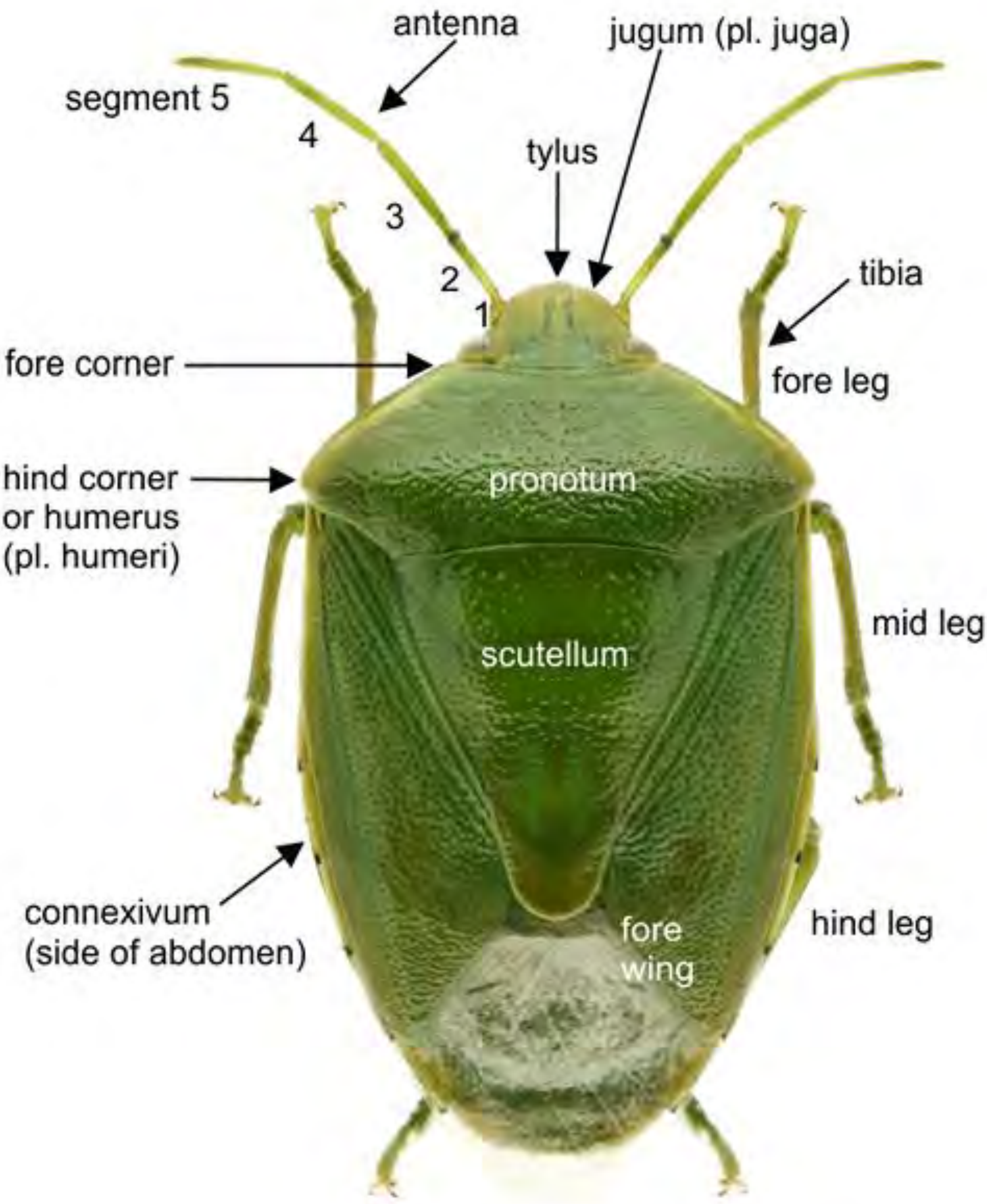

Figure 2.7. Body structure of *Hemiptera* (from dorsum) [5]

Habitat. Almost all members of this order are terrestrial. Most *Hemiptera* are found on the leaves, stems, bark of plants, among the roots. They may aggregate in enormous numbers.

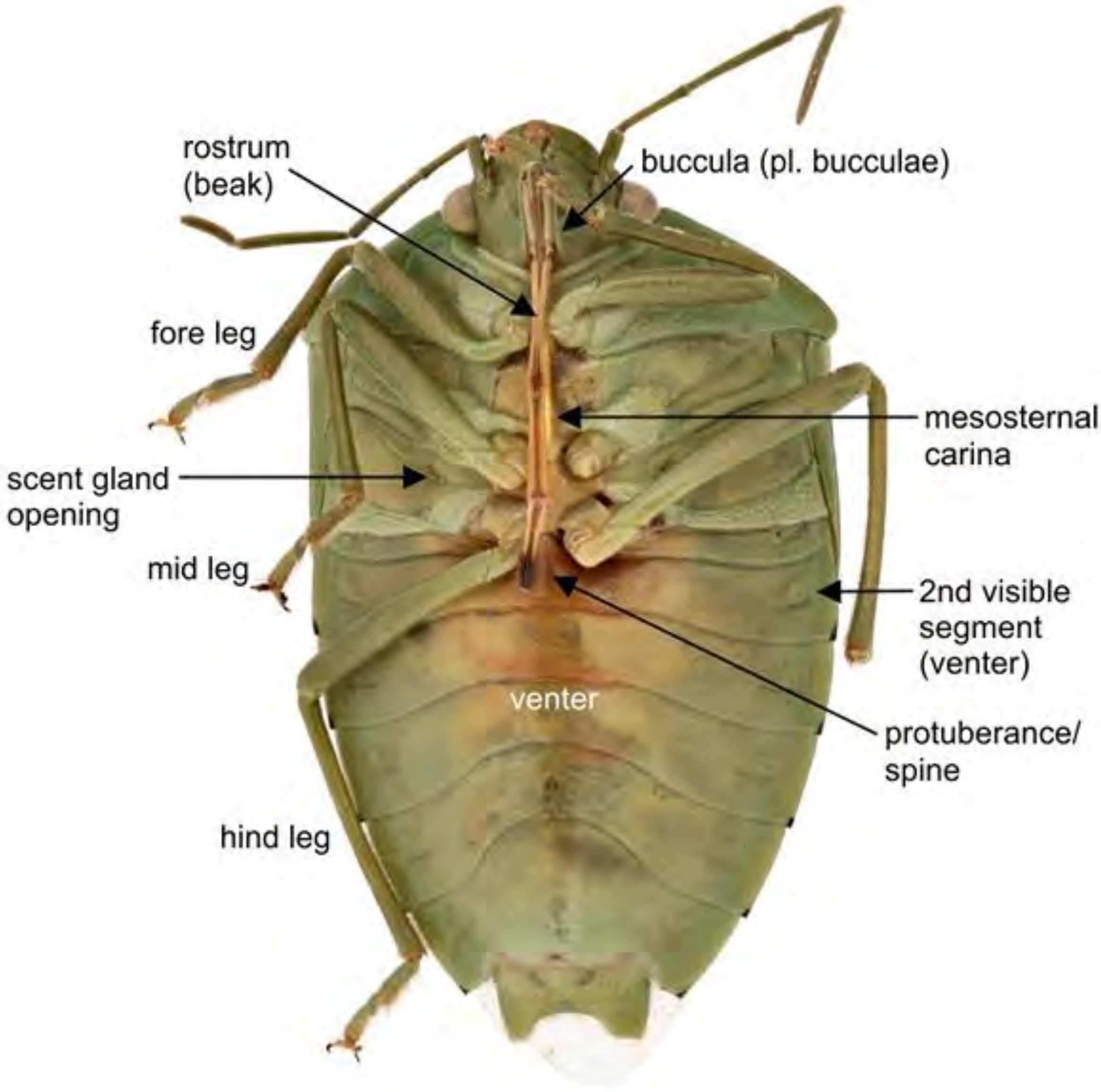

Figure 2.8. Body structure of *Hemiptera* (from abdomen) [5]

Lepidoptera are presented of moths (Fig. 2.9) and butterflies (Fig. 2.10). It is one of the most widely recognizable orders in the world. Members of this order have two pairs of membranous wings. Some moths are wingless. They have scales that cover the bodies, wings, and a proboscis. These scales are modified and give butterflies or moths a wide variety of patterns and colors. They have large composite eyes, antennae present. Butterflies have antennae of different types. Mouthparts of *Lepidoptera* are formed into a sucking tube. Their larvae have a sclerotised head with chewing mouthparts, three pairs of legs, and often short prolegs on the abdomen.

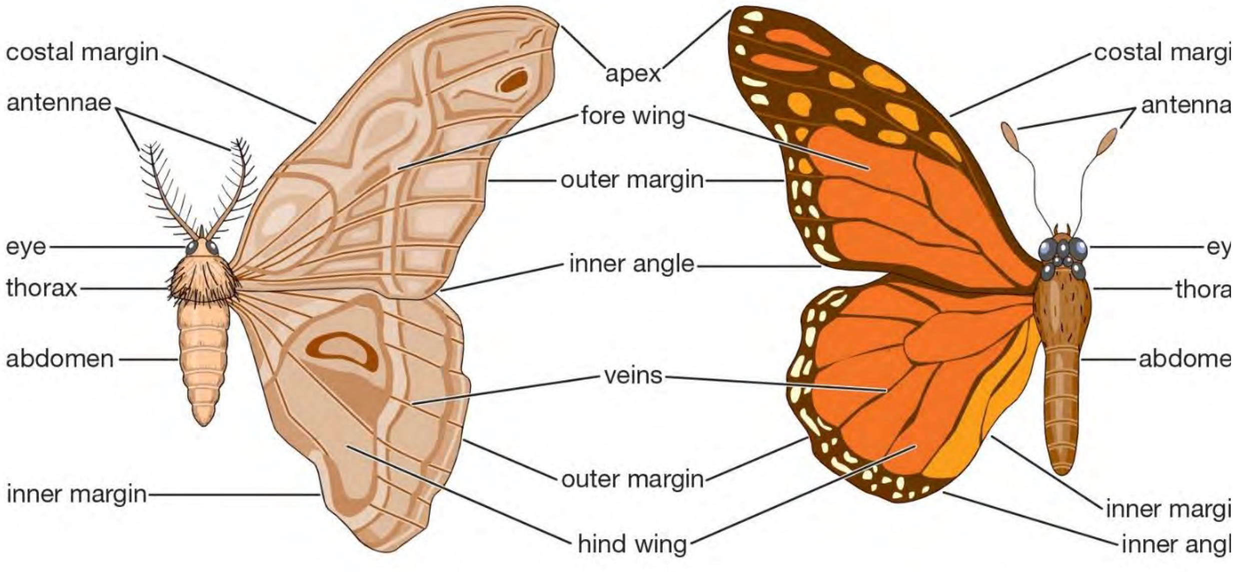

Figure 2.9. Body structure of *Lepidoptera* (Moth) [6]

Figure 2.10. Body structure of *Lepidoptera* (Butterfly) [6]

Life cycle. Butterflies and moths undergo a complete life cycle that includes four stages (Fig. 2.11, 2.12): egg, larvae (caterpillar), pupae, and adult. The eggs are often laid on the caterpillar's food plant. A female may lay from a few eggs up to tens of thousands depending on the species. After hatching caterpillars usually develop for up to a few months and then pupate. Many butterflies and moths have one or two generations each year.

Figure 2.11. *Cossus cossus* L. (Larva)

Feeding. Most larvae of butterflies and moths are herbivores either eating foliage or wood. Some are carnivorous. They cannibalise other caterpillars or feed on soft-bodied insects. Adults generally feed by nectar. Some *Lepidoptera* do not eat at all.

Habitat. The range of butterflies' and moths' food plants determines their distribution. Adult butterflies generally fly near their food plants. Moths are mostly nocturnal.

Figure 2.12. *Zeizera pyrina* L. (Imago)

Hymenoptera is a large order of insects, comprising sawflies, bees, wasps, and ants. They have two pairs of membranous wings (Fig. 2.13). The forewings are larger. Some *Hymenoptera* may be wingless. Most of them have a constriction between the first two segments of the abdomen. They have chewing mouthparts, compound usually large eyes. The bee mouthparts have been modified to form a long tube and a hairy glossa which they use for sucking up nectar from flowers.

Hymenoptera is divided into two suborders: the *Symphyta* (sawflies, who have no discernible waist) and *Apocrita* (bees, ants, and wasps, who have a distinct waist).

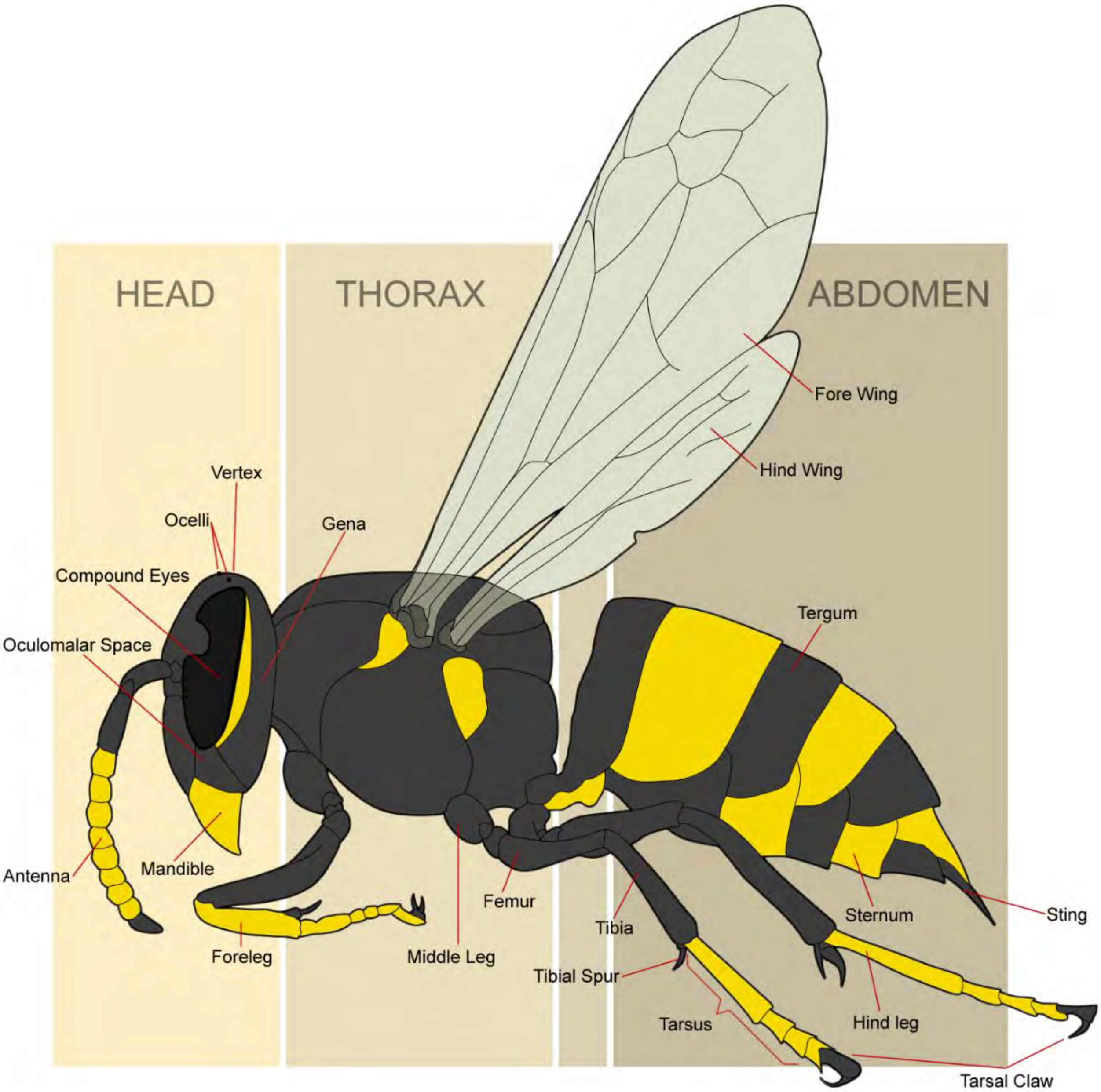

Fig. 2.13. Body structure of *Hymenoptera* [7]

Life cycle. *Hymenoptera* have a complete life cycle. Some females can produce progeny without mating. Other ones can store sperm and spread out their egg-laying. Most species of this order lay their eggs on the appropriate host plant.

The larvae molt several times before they pupate. Development may range from a few weeks to much longer.

The feeding of *Hymenoptera* depends on species. Adult wasps mostly feed by nectar and honeydew. Some species are predators or parasitoids, spending their time searching out hosts to lay their eggs on. The feeding habits of adult ants vary.

Hymenoptera are highly susceptible to habitat loss, which can lead to substantial decreases in species richness. That can have major ecological implications due to their role as plant pollinators.

Diptera includes many familiar insects such as flies, mosquitoes, and midges. Many species of *Diptera* transfer infection, for example malaria. They have one pair of membranous wings, sucking mouthparts, large compound eyes, and short simple antennae (2.14).

Life cycle. *Diptera* has a complete life cycle. They mate while flying. The eggs are usually laid into the suitable substrates (soil, organic matter, water, plant or animal tissue) or close to a food source. The larvae of *Diptera* complete their development and pupate in the substrate where they were laid.

Feeding. Adults of *Diptera* are only able to ingest liquid foods. The larvae mostly feed on moist, decomposing organisms, particularly animals and fungi. The larvae of *Comptosia* insignis parasitise the larvae of other insects and prey on the eggs of grasshoppers and locusts.

Habitat. Members of *Diptera* are found in almost all types of terrestrial and freshwater habitats, forests and water margins.

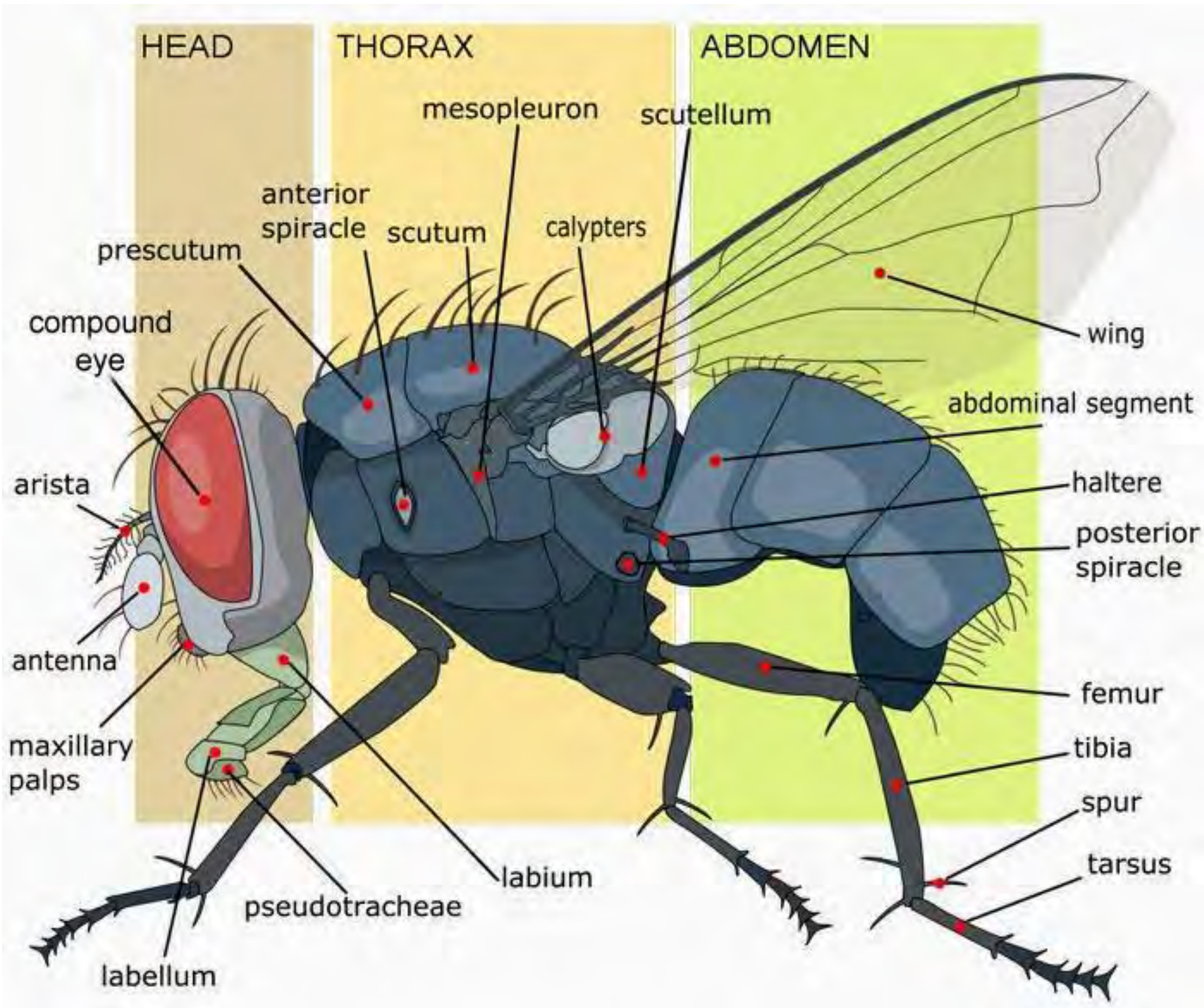

Fig. 2.14. Body structure of *Diptera* [8]

2.2. Consequences of insects' activity

Plant injury is a possible indication of an infestation. Knowing the types of injury caused by various insects can be a clue to the identity of the pest. Insects cause damage to leaves, needles, and buds: gnaw, grind, suck out them, and inject poisonous substances into plant cells with saliva. Insects may transmit fungal, viral, bacterial infections and infect plants.

Phytophagous insects are divided into groups depending on the site of damage. According to organs and parts of plants damaged, the following groups of phytophagous are distinguished: leaf- and needle-eating insects, root insects and stem insects (xylophagous), aboveground part of woody plants insects, etc. Deciduous woody plants renew eaten leaves in the same year in favorable conditions. However, when phytophagous consume the leaves for several years, the plants begin drying and withering. Highly damaged conifers sometimes begin to wither in the current year. At 100 % needles loss, conifers often die.

Needle-eating and leaf-eating insects. Most needle-eating and leaf-eating insects belong to the orders *Lepidoptera*, *Heminoptera* and *Coleoptera*. Their larvae partially or completely devour the assimilation apparatus of the plants. Eating leaves and needles leads to defoliation and is accompanied by disruption of the physiological functions of trees: transpiration, photosynthesis, respiration, etc.

Among of the significant number of needle-eating and leaf-eating insects, we will consider only phytophagous, which propagate in masse and cause significant damage to tree stands. Their outbreaks are repeated in large areas. Most insects of this group belong to the order *Lepidoptera*: *Dendrolimus pini* L., *Malacosoma neustria* L., *Lymantria monacha* L., *Lymantria dispar* L., *Euproctis chrysorrhoea* L., *Dasychira pudibunda* L., *Leucoma salicis* L.; *Panolis flammea* Schiff., *Bupalus piniarius* L., *Boarmia bistortata* Goeze, *Operophthera brumata* L., *Erannis defoliaria* CL., *Zeiraphera diniana* Gn., *Phalera bucephala* L., *Notodonta anceps* Goeze., *Tortrix viridana* L., *Archips crataegana* Hb., *Aporia crataegi* L., *Hyphantria cunea* Drury., *Acrocercops brongniardella* F., *Thaumetopoea processionea* L. Some belong to an order *Hymenoptera: Diprion pini* L., *Neodiprion sertifer* Geoff. And leaf-eating insects of *Coleoptera* order the next: *Chrysomela populi* L., *Chrysomela tremula* F., *Pyrrhalta viburni* Paycull, *Haltica saliceti* Weise, *Lytta vesicatoria* L.

Insects of this group are characterized by the ability to change fertility and rapidly increase population number under favourable environmental conditions. The population may change in some years. Many species of this group do not feed in the adult stage. Damage to the assimilation apparatus by these insects leads to a decrease of tree increment. The risk of tree mortality after damage by needle-eating and leaf-eating insects increases in dry years, especially in the presence of the bark beetle populations in the forest.

Damage by phytophagous insects causes tree weakening, reducing their decorative properties, brings to deformation of branches and stems, drying up tops.

Table 2.1. Damage of leaves, needles and buds by insect pests

Insects and others	Damage
Aphids	Deformed leaves, sucking damage
Trips and mites	Discoloured leaves, sucking damage
Beetles, caterpillars, sawflies	Chewed or skeletonized leaves
Cynipid wasps, certain aphids, psyllids, and mites	Leaf galls (abnormal plant growths)
Beetle, fly, or moth larvae	Leaf mines (white patterns on leaves)
Caterpillars, tree crickets, and spiders	Folded leaves, leafroller damages
Slugs and snails	Chewed leaves, slime trails
Beetles, moths, borers, caterpillars	Punctures

Sucking damage and deformed leaves. Symptoms of sucking damage are wilting, leaf yellowing, or defornation, a buildup of honeydew or sooty mold. Sap feeders suck cell water or feed on the tender tissue of the leaf underside.

The chewed and skeletonized leaves. Chewing insects make holes in leaves (Fig. 2.15). Several insects chew rounded holes in the middle of leaves, and others feed from the edges of the leaves. Caterpillars may feed off leaves leaving a skeleton-like effect (Fig. 2.16).

Fig. 2.15. The chewed leaves

Fig. 2.16. The skeletonized leaves

Galls are irregular plant growths (Fig. 2.17, 2.18). They can occur almost anywhere on a plant and may be caused by insects, fungi, bacteria, or nematodes. About 80 % of galls are produced by genus *Diplolepis*. Aphids, psyllids and mites can be the causes of, too. Many galls occur on oaks, less – on the willows. Galls usually are formed in the time of bud break. Gall makers inject chemicals into the leaf during egg laying or as the insect develop. Galls rarely affect tree health but other than early leaf drop. They just provide food and protection for the inhabitant.

Fig. 2.17. Leaf galls


Fig. 2.18. Leaf galls

Discoloured leaves. Leaves and needles of plants occasionally lose their green color. The key reason that plants turn yellow is that they are not able to maintain an adequate content of chlorophyll (the green pigment). When this substance is absent, yellow pigments take over and the leaves or needles fade. Sucking insects such as aphids remove nutrient sap from the plants restricting their ability to maintain chlorophyll.

Leaf miners damage. Leaf miners feed on within leaves, producing winding tunnels of dead tissue (Fig. 2.19, 2.20). They feed on internal cells. Leaf miners include caterpillars

(*Lepidoptera*), sawfly larvae (*Hymenoptera*), beetle and weevil larvae (*Coleoptera*), and larvae of true flies (*Diptera*).

Fig. 2.19. Leaf mines

Leafroller damages are usually minor. Some years they may be quite severe. Defoliation can occur because of lots of nests on a plant. High numbers of leafrollers may also feed on fruits, causing their deformation and scarring. There are a lot of woody plant species and fruit trees which are affected by leafrollers (Fig. 2.21, 2.22).

Fig. 2.20. Leaf mines

Leafrollers are represented by *Lepidoptera* (*Tortricidae*) and *Coleoptera* (*Rhynchitidae* and *Attelabidae families*). *Leafrollers* (the larvae of certain tortricid moths) often feed and pupate within the protection of rolled-up leaves. Several species can cause problems in forests and gardens, for example, *Tortrix viridana*, *Archips crataegana*, *Archips rosana*, etc.

Leaf roller weevils typically damage the vegetative and reproductive organs of plants (leaves, shoots, buds, and fruits), causing their wilting and decay. Eggs are then laid into thus prepared tissues or between the folds of the leaves in species-specific leaf rolls (Fig. 2.23, 2.24). Larvae live endophytically in the damaged organs or inside the leaf rolls, which either persist on the plants or eventually fall onto the ground. The examples of leaf roller weevils are *Byctiscus betulae*, *Byctiscus populae*, and *Deporaus betulae*.

Fig. 2.21. Leafroller damages

Punctures. Larvae of flower-eating beetles damage the inner parts of the buds. The holes on the bud surface are small with a diameter of 0.2-0.3 millimetres, with a channel inside the bud. Often drops of juice protrude from a damaged bud ("weeping buds").

Fig. 2.21. Leafroller damages

Fig. 2.23. Leaf-rolling weevils

Fig. 2.23. Leaf-rolling weevils

Stem damaging (xylophagous) insects. Significant damage to forests are caused by bark beetles. Reproducing in large numbers, bark beetles lead to the mortality of individual trees or entire forests. Bark beetles' foci develop against the background of reduced resistance of trees or stands under the influence of certain environmental factors. Favourable conditions for the development of stem insects are created in the stands with impaired resistance. Such insects become additional factors of a negative impact and lead to partial or complete disruption and death of the stand (Fig. 2.24).

Bark beetles live beneath the bark of host trees in galleries that are unique for each species. Signs of bark beetle activity include pitch tubes on the bark surface, egg galleries (tunnels), larval mines beneath the bark.

Stem pests include insects of the family *Curculionidae*, *Cerambycidae*, *Buprestidae*, *Siricidae*, *Cossidae*, and others.

Bark beetles that are common on conifer species: *Tomicus piniperda* L., *Tomicus minor* Hartig, *Ips sexdentatus* Boerner, *Ips acuminatus* Gyll., *Trypodendron lineatum* Ol., *Ips typographus* L., *Ips duplicatus* Sahl., *Pityogenes chalcographus* L., *Dendroctonus micans* Kug., *Monochamus galloprovincialis* Ol., *Acanthocinus aedilis* L., *Spondylis buprestoides* L., *Monochamus sutor* L., *Phaenops cyanea* Fr., *Anthaxia quadripunctata* L.

Bark beetles that are common on deciduous species: *Scolytus intricatus* Ratz., *Xyleborus dispar* Fabr., *Scolytus scolytus* F., *Scolytus ratceburgi* Jans., *Hylesinus crenatus* F., *Hylesinus fraxini* Panz., *Cossus cossus* L., *Zeuzera pyrina* L.

Root damaging insects. Root insects are one of the most common and harmful groups of pests. They cause great damage in forest nurseries and crops. In old stands, their harm is much less. Root insects include larvae of cockchafers, wireworms, caterpillars of *Noctuidae*, larvae of some weevils, etc. The most common and harmful among them are the larvae of cockchafers. Cockchafers belong to the family *Scarabaeidae*. By damaging the roots of plants, especially seedlings and saplings of trees and shrubs, they cause great damage. The most dangerous *Scarabaeidae* are

Melolontha hippocastani F., *Melolontha melolontha* L., *Polyphylla fullo* L., *Anoxia pilosa* F., *Amphimallon solstitialis* L. Many species of *Scarabaeidae* are completely harmless or cause little damage, such as large larvae of the rhinoceros beetle, which live in manure and compost heaps.

Insects of forest crops. Damage to forest crops by phytophagous affects their growth and condition, can cause deformation of stems and branches, and, often tree mortality. Insects of forest crops are divided into groups. Some of them damage to deciduous woody plants, the others damage to coniferous. In each of these groups, there are insect species that damage buds, shoots, leaves, needles, trunks, branches, roots, etc.

Leaf-eating insects in forest crops are presented by the following species of *Aphidodea*: *Aphis pomi* De Geer, *Viteus vitifoliae* Fitch, *Phylloxera coccinea* Heyden, *Tetraneura ulmi* L., *Tetraneura coerulescens* Passerini, *Hyalopterus pruni* Geoffr., *Eriosoma lanigerum* Hausmann, *Eriosoma ulmi* L., *Lachnus roboris* L. The most common among *Chrysomelidae*: *Melasoma tremulae* Fabricius, *Agelastica alni* L., *Haltica quercetorum* Foudr., *Melasoma aenea* L., *Melasoma populi* L., *Galerucella luteola* Muell. The most common species of the family *Meloidae* are *Lytta vesicatoria* L. Family *Cynipidae* has the next species: *Diplolepis quercus-folii* L., *Andricus foecundatris* Hart.

The needle-eating insects. Among the most harmful for forest crops are the representatives of order *Hemiptera*. Especially species *Adelges larids* Vail. of family *Adelgidae* and most species of families *Aphidodea*, *Diaspididae*, *Coccodea* and *Pseudococcidae*, which parasitize almost all coniferous ornamental woody plants.

Insects of buds and shoots of conifers. The most common representatives of order *Lepidoptera* are: *Evetria buoliana* Schiff., *Evetria duplana* Hb., *Evetrla lurionana* Hb., *Dioryctria abietella v. pinetella* Rodz.

Insects of stems and branches of deciduous species. The most common species from an order *Coleoptera is Saperda populnea* L., and from order *Lepidoptera* is *Sciapteron tabaniforme* Rott.

Fig. 2.24. Stem damage by bark beetles

2.3. Live cycles of insects

Insects are mainly heterosexual and their populations consist of males and males. Sometimes there is polymorphism. Different forms of one species have special functions. Most insects can reproduce very quickly. Most insects reproduce by laying eggs. The female produces eggs. The male fertilizes them. Some insects have asexual reproduction. In this case, the offspring comes from a single parent. This is characteristic to aphids and scale insects.

There are two main types of insect transformation – hemimetabolism and holometabolism. Hemimetabolism (incomplete metamorphosis) is the mode of development of certain insects. Hemimetabolism includes three distinct stages: the egg, nymph, and the adult stage, or imago (Fig. 2.25). Holometabolism (complete metamorphosis) is known as a form of insect development, which includes four life stages (Fig. 2.26): egg, larva, pupa, and imago (adult). Some insects build cocoons during the pupal stage of development. This is when the most changes in the insect's appearance and behavior occur. The cocoon defends the insect while it cannot defend itself.

The life of an insect begins as an egg. After leaving the egg, the insect grows, transforms and becomes an adult. The adult insect can reproduce. The transformation of an insect in life cycle is known as metamorphosis.

A generation is a part of the population from the stage in the life cycle to the same stage in the offspring. Generation time is the period required to complete a generation.

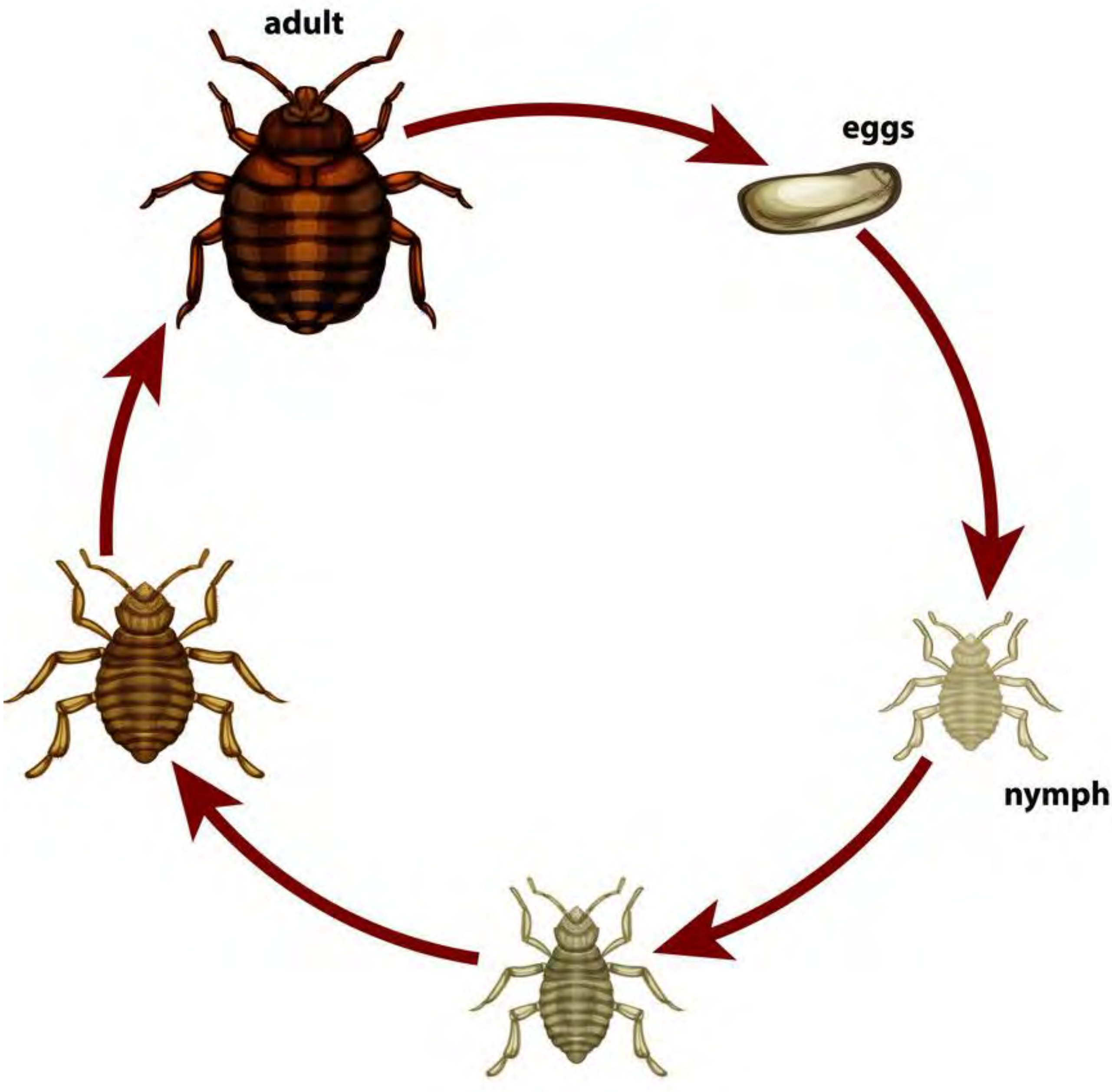

Fig. 2.25. Life cycle of insects (hemimetabolism) [9]

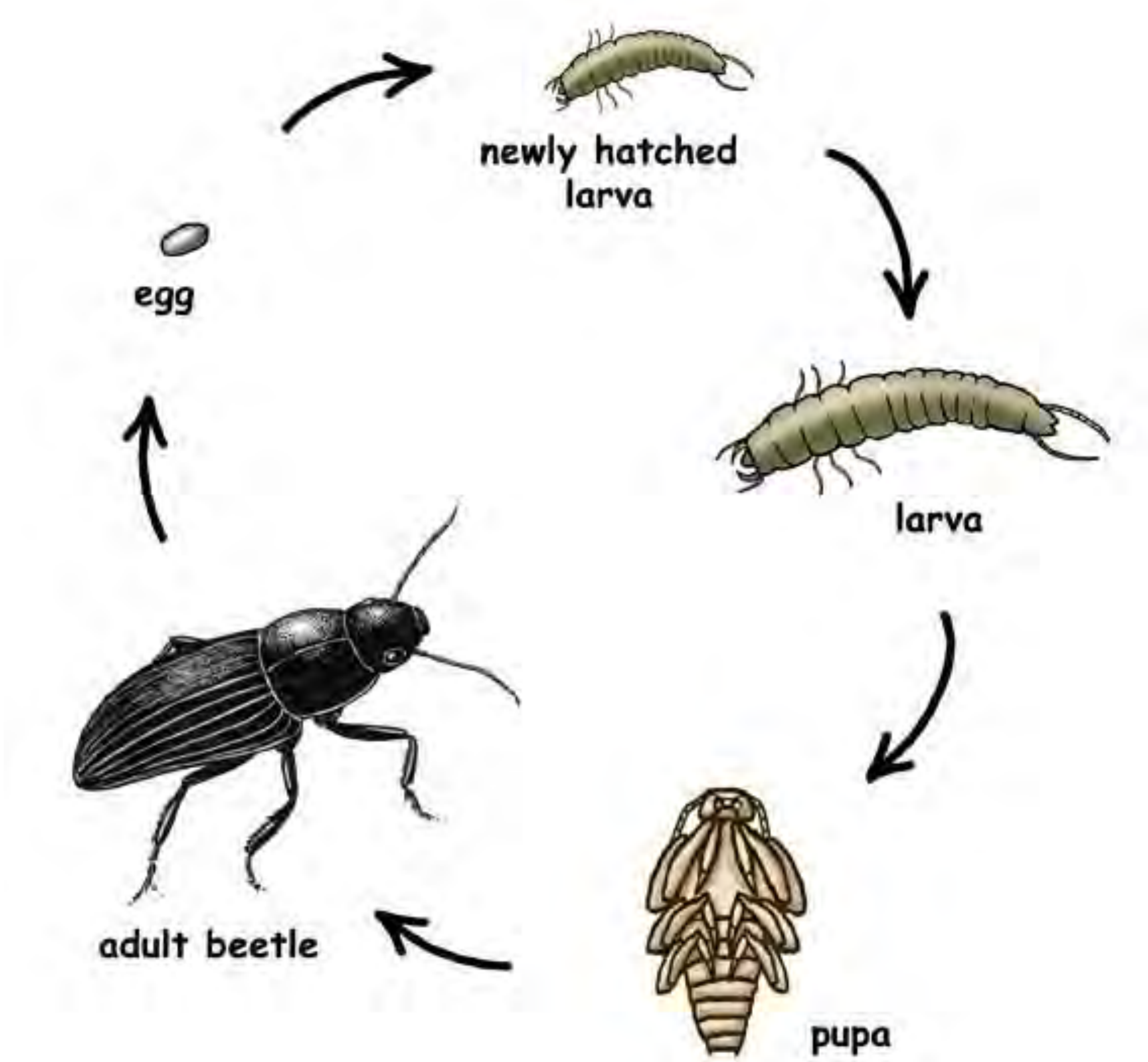

Fig. 2.26. Life cycle of insects (holometabolism) [10]

There is such a phenomenon as mimicry in the life of insects of some species (Fig. 2.27). It is an evolved resemblance between an organism and some object, usually an organism of another species. Mimicry functions to protect a species from predators. The resemblances often can be visual.

Biologists define mimicry as one organism replicating the physical or behavioral traits of another organism. Mimicry can be inter- or intraspecific, occurring between individuals within the same species or between different species.

Fig. 2.27. Examples of mimicry [11, 12]

Insects are characterized by dimorphism and polymorphism.

Dimorphism is the presence of two different forms of an organism in a population, namely males and females have a different appearance.

Polymorphism is appearance of forms differing in colour and number of attributes within a single species. Many types of polymorphism can be seen in *Lepidoptera*.

CHAPTER 3. INSECT OUTBREAKS

3.1. Patterns of insect outbreaks

The populations of all living organisms, including insects, are not constant over time. Insect populations change under the influence of weather conditions, forage properties of host plants, intrapopulation and interpopulation interactions.

Some insects are characterized by a sudden increase in abundance, the so-called *outbreaks*. Outbreaks of Egyptian locusts in northern Africa and the Middle East have been known since the Old Testament. In old chronicles, outbreaks of *Lymantria monacha* are described. Everybody saw large groups of *Melolontha* beetles in certain years.

Outbreaks are not characteristic of all insects. Outbreaks of phytophagous pests of agriculture and forestry are the most studied. A significant increase in the abundance of these insects can lead to the loss of a certain tree species in the stand composition, a decrease in their productivity, the yield of fruits and seeds, and a violation of the ecological functions of the forest.

The study of the biological characteristics of forest insects and the patterns of their outbreaks is necessary for effective forecasting of their population dynamics and timely planning of measures to reduce damage to the forest and forest management.

Phytophagous insects are divided into indifferent, prodromal, and eruptive species according to their ability to cause outbreaks. Thus, the abundance of indifferent species in multi-year dynamics varies slightly relative to the background level. Prodromal and eruptive species are capable of considerably increasing the population, which in prodromal species fluctuates near the lower stationary level, and in eruptive species, it sometimes remains at the level of the upper stationary level of the phase portrait for several generations without losing the ability to regulate the population size.

Eruptive species are the most dangerous for the forest. Such species are represented mainly among foliage-browsing insects and some xylophages. However, the same species can be eruptive in one region and prodromal in another region or in certain years.

3.2. Global factors of outbreaks

Outbreaks often occur simultaneously in different regions under the influence of global factors.

Solar activity is one such global factor.

The terms “solar activity” and “solar radiation” should not be confused.

Solar radiation is radiation from the Sun that spreads in the form of electromagnetic waves at a speed of 300,000 km/s and penetrates the Earth's atmosphere. Due to the ozone layer and the filter in the form of water vapor, carbon dioxide, and dust particles suspended in the air, the harmful parts of the radiation are delayed. The infrared part of the radiation, which carries heat to the Earth, comes to its surface at different angles that depend on the latitude. Depending on the Sun position, the temperature changes throughout the year. At the equator, it changes less, and in the temperate zone, four seasons replace each other.

Solar activity is a complex of phenomena and processes associated with the formation and decay of strong magnetic fields in the solar atmosphere.

For about two centuries, researchers from various fields of knowledge have been trying to identify and explain the relations between Earth processes and solar activity (SA). Thus, cycles lasting 5–6, 11, 22–23, 33–35, 80–90, 500, and 1800–1900 years were found in SA fluctuations. Similar cycles are described when studying the frequency of magnetic storms, ultraviolet radiation, the degree of ionization of the upper layers of the atmosphere, the level of lakes, and meteorological events.

In the years of sharp changes in solar activity (so-called benchmark years), breaks in the long-term course of many natural processes on Earth were also recorded.

Solar activity and its changes directly affect atmospheric processes, and indirectly - the spread of the plant, animal, and people diseases, crop yields, tree increment, and fluctuations in the fish, bird, rodent, and insect populations.

Solar activity creates a “cyclical background” of changes in terrestrial processes and the distortion of this background. The cyclical background is manifested in the form of a relationship of terrestrial processes with the hundred-year cycle of solar activity, and distortion - in the form of a relationship with years of its sharp changes.

The coincidence of processes does not mean that one of them is the cause of the other. They may simply coincide. We cannot claim that solar activity fluctuations are the causes of insect population fluctuations, but these solar activity fluctuations coincide with changes in some terrestrial processes (e.g., seasonal temperature, moisture level), which can already directly or indirectly (e.g., through food) affect population dynamics of insects. However, the level of solar activity can be predicted several years ahead quite accurately, as measurements have been carried out for several centuries at various points on the globe at a high methodical level. Therefore, if changes in solar activity are not the cause of fluctuations in the insect populations, but coincide with them, or even better - are detected earlier, then information about expected changes in solar activity can be used to some extent to forecast insect outbreaks.

3.3. Local factors of outbreaks

At the same time, the outbreaks occur in certain subcompartments of the stand (so-called foci) and do not occur in others.

The *focus* of mass propagation is the plot (a couple of plots) of the stand where populations of one or several insect species increase up to a level at which significant economic and/or environmental damage is caused.

According to the classical scheme, the outbreaks of foliage-browsing insects go through four phases. During the first (initial) phase, the population size increases by 2–4 times compared to the number before the outbreak. During the second (prodromal phase, or the phase of population growth), foci are formed. During the third phase (eruptive, actual outbreak), the number of individuals increases hundreds of times, and during the fourth (crisis) it sharply decreases. At the same time, an outbreak of bivoltine species lasts 4 years, an outbreak of monovoltine species – for 7 years, and an outbreak of insects with a two-year cycle (semivoltine) lasts 14 years. However, when the environment is unfavorable for insects, the duration of the second phase of the outbreak may increase, and the third and fourth may be reduced.

During 1978–2008, the outbreak duration of foliage-browsing insects in different regions of Ukraine ranged from 3 to 7 years. The lowest value (3 years) is registered in the western regions of Ukraine (Volyn, Zhytomyr, Rivne), is 4 years in the central regions, and exceeds 5 years in the eastern and southern regions. The shortest duration of outbreaks in the western and northern regions of Ukraine can be explained by the more effective action of regulatory factors in Polissya, where environmental conditions are favorable for forests.

Differences in the duration of outbreaks of individual foliage-browsing insects are associated with their seasonal development. *Tortrix viridana* has the most prolonged outbreak (5 years) because it has the shortest period of vulnerability to regulatory factors (its larvae develop in about 30 days). The duration of outbreaks of *Lymantria dispar*, whose caterpillars feed until the end of June, is about 4 years. The shortest duration of outbreaks (3 years) is observed in *Panolis flammea*, the pupae of which are vulnerable to the action of abiotic and biotic factors for several months (including summer ones).

However, the frequency, severity, and duration of outbreaks can be different even in the adjacent subcompartments because of features of stand structure, microclimate and conditions for entomophagous insects.

Outbreaks of foliage-browsing insects under favorable global conditions are most frequent in regions with a more continental climate, in illuminated and warmed forest plots. Such plots are characterized by the low relative density of stocking and low density of undergrowth, that neighbour with unclosed plantations, burnt areas, and clear-cuts. In these plots, the larvae hatch in the presence of attractive food. Their rapid development allows them to escape the entomophagous insects that hibernate in the litter and soil. In illuminated areas, polyhedra and spores of insect pathogens (so-called entomopathogenic microorganisms) are inactivated the fastest, and the conditions for wintering and maturation feeding of entomophagous insects worsen.

The dynamics of insect populations were studied in two main directions – mathematical models and ecological theories.

The basis for statistical models of insect population dynamics is the analysis of survival, mortality, population reproduction coefficients and factors affecting them, including meteorological elements. Examples of the simplest models can be equations of relationships between the population size in the following and previous years or the dependence of adult fecundity on pupae size and mass. Multiple regression models considered different features of insects, host plants, and environment.

3.4. Theories explaining insect outbreaks

Many researchers associate fluctuations in the insect populations only with factors that depend on population density, namely intra- and interspecies competition, or the influence of entomophagous insects and diseases. According to *parasitic* theory, the population of phytophagous insects increases. Subsequently, competition for food resources and the population number of entomophagous insects increase. As a result, the population of phytophagous insects decreases.

According to *climatic* theory, the main role in cyclical fluctuations in the insect population belongs to the direct action of meteorological factors, particularly temperature, humidity, and precipitation or integral indices (hydrothermal coefficient, coefficient of winter stiffness, etc.). However, taking into account meteorological parameters for strictly specified dates leads to errors in forecasting. This is related to the variability of the timing of the insect development after wintering in different years and in certain subcompartments of the stand, which is reflected in the timing of critical periods (we do not know which stage of the pest will fall under certain weather conditions, what proportion of the population will be in the vulnerable stage at the time of such phenomena; the weather forecast is not very accurate, rain may be in one part of the forest and be absent in another).

According to the *trophic theory*, fluctuations in the insect population occur under the changes in plant quality, which depend on the dynamics of the contents of protective substances in plants of different physiological condition. This theory explains the influence of foliage quality on the dynamics of insect populations, as well as the relationship between the nutritional and protective properties of foliage with forest site conditions. However, it does not allow forecasting the next outbreak (young leaves contain more nitrogen, which is favorable for the rapid larvae growth and imago fecundity, and few protective substances (phenols, and tannins). The rates of insect development and viability also depend on the ratio of these substances.

These theories, which explain the dynamics of insect populations (parasitic, climatic, trophic), are called “factorial” since each of them takes into account only one aspect of the insect’s interaction with the environment. This narrows the limits of the application of these theories, but the accumulated factual material has been used in the development of other theories of the dynamics of forest insect populations.

According to the *synthetic* theory, fluctuations in the populations are controlled by a complex of natural mechanisms that, based on the principle of feedback, smooth out the fluctuations that arise and ensure the stability of the system. At the same time, under the influence of factors unrelated to population density (mainly weather conditions), a **modification** occurs, which is manifested through random deviations in the abundance, as a result of which the population increases under favorable conditions for a certain species. After reaching the maximum insect abundance, the effect of **regulatory** factors increases, the effect of which depends on the population density. The higher the density of phytophages, the better the conditions are for their natural enemies and diseases. As the abundance of phytophages increases, their competition for habitat and food increases. That is, regulatory factors include biocenotic and intraspecific factors. This theory also explains well the population dynamics of foliage-browsing insects but does not provide ways of forecasting subsequent outbreaks.

The phenological theory explains the diversity of the dynamics of individual populations of foliage-browsing insects by the differences in the relationships between the dates and rates of development of the host plant and phytophagous insect, phytophagous and entomophagous insects. These differences are caused by different ratios of air and soil warming rates and dates in different years, regions, and stands.

It is known that most often outbreaks are characteristic of insect species that feed in the spring. The timing of spring natural phenomena is characterized by the greatest variability as a result of which, in some years, the synchrony of phytophagous larvae and host tree development, as well as the synchrony of entomophagous and phytophagous insects, is disturbed.

Outbreaks of foliage-browsing insects, whose larvae feed in July-September, are recorded less often because the synchronization of their development both with changes in food and with cycles of entomophagous insects plays a smaller role. Thus, the biochemical composition of leaves in the second half of summer is practically stable, and non-specific entomophagous insects at this time are in a high number, propagating for several generations in different host insects.

3.5. Outbreaks of other ecological groups of forest phytophagous insects

Unlike foliage-browsing insects, outbreaks of other ecological groups primarily depend on the availability of breeding substrate.

Pests of fruits, cones, and seeds increase in abundance in harvest years, and in lean years, the “reserve” part of the population is in diapause.

Pests of unclosed plantations are able to migrate to other suitable stands when the plantations close. The more afforested clear-cuts and burnt areas are in the neighborhood, the greater the threat of the spread of these insects.

Xylophagous insects in a healthy forest populate drying branches and trees, accelerating the cycle of organic matter. Most of these insects are not aggressive, that is, they are not able to attack healthy trees. In the event of natural disasters (fires, storms, floods) or forest weakening under anthropogenic factors, the number of trees susceptible to colonization increases.

Bark beetles inhabit such trees and increase their populations. This allows them to colonize less weakened trees due to the simultaneous attack of a large number of beetles. However, one tree can be inhabited only by a certain number of beetles. Competition arises between individuals of the same species, as well as between different species, as a result of which the most adapted individuals win. For example, the species have the advantage if they swarm earlier or are capable to populate both trees and stumps and logging residues. Some bark beetles perish, and others migrate to other stands and continue to populate only severely weakened trees.

The foci of stem pests may be episodic, chronicle, or migrative.

Episodic foci arise as a result of simultaneous weakening or damage to the tree stand (by fire, hurricane, etc.). Such foci collapse mainly after 3-4 years. Chronic foci arise at chronic weakening or damage to the tree stand by root rot, industrial emissions, etc. In chronic foci, the abundance of stem insects is relatively low but remains unchanged for several years. Migrative foci (foci of dispersal) occur near episodic or chronicle foci as a result of insect dispersal.

In the foci of all types, an outbreak of stem insects develops through three main phases:

– initial (increase in abundance, concentration);

– actual outbreak (maximum abundance);

– crisis (dispersal).

Each phase of outbreak development is characterized by a certain distribution of trees by health condition and certain values of the main population parameters of stem insects. The proportion of weakened trees in the first phase increases, in the second phase – decreases, and in the third phase sharply decreases.

The proportion of trees inhabited by stem insects exceeds natural mortality at the beginning of an outbreak by 2-3 times, during the second phase by 3-5 or more times, and in the crisis phase, it is equal to or slightly exceeds the natural tree mortality. At the same time, as the outbreak progresses, the proportion of the trees of the 6th class of the health condition increases.

CHAPTER 4
ECOLOGICAL GROUPS OF DISEASES IN FOREST

4.1. Causes of plant diseases

The disease is a violation of the normal metabolism of cells, organs and even the whole plant. Plant diseases are broadly classified according to the nature of their primary causal agent. The disease of wood plants (Fig. 4.1) can be caused by exposure to pathogens (infectious origin) or adverse environmental conditions (non-infectious origin). Disease can lead to reduced productivity of woody plants and their death.

Fig. 4.1. Groups of diseases

Infectious diseases are caused by fungi, bacteria, viruses, mycoplasmas and nematodes. Fungal diseases are the most common in forest plants are. Diseases caused by fungi are named mycoses, by bacteria – bacterioses.

Non-infectious diseases are caused by unfavourable abiotic factors due to sharp fluctuations of humidity, air temperature, insufficient light, soil nutrition, exposure to toxic substances, and inadequate plant nutrition. Such diseases cannot spread from plant to plant, but are very common and should be considered when assessing the health of any plant.

Diseases are associated with specific signs and symptoms.

The disease triangle is a model that shows the interactions between the environment, the host, and a pathogen (Fig. 4.2). This model can be used to predict epidemiological outcomes of plant health.

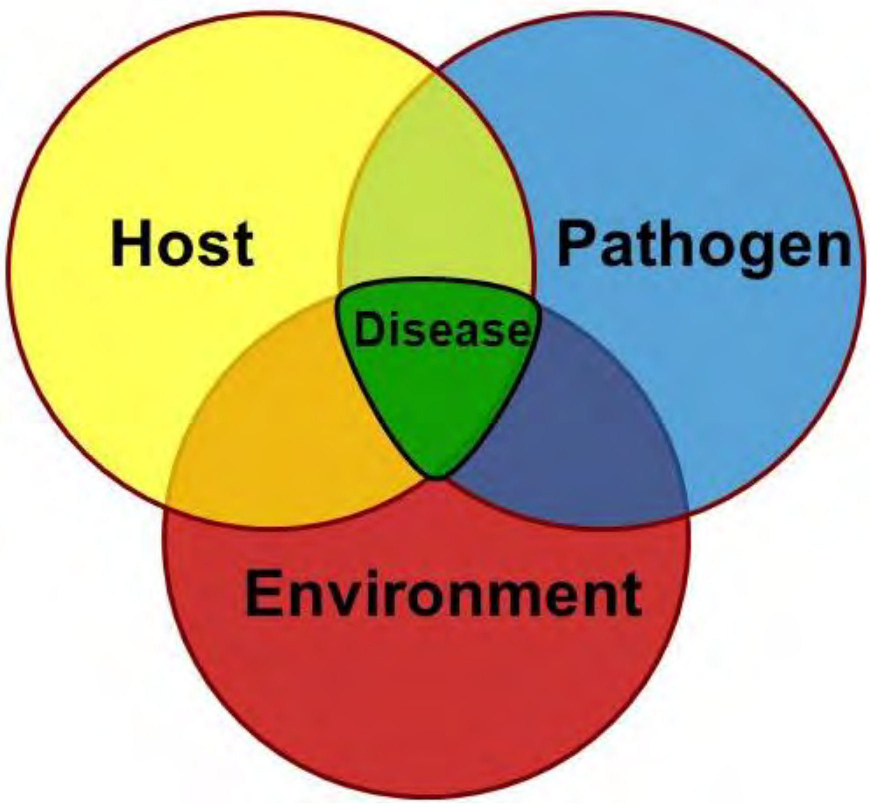

Fig. 4.2. The disease triangle [13]

The disease occurs when there are three components: host, pathogen, and environment. The host is stressed or injured plant.

Pathogen capable to cause the disease (many of them are host specific). The environment contributes to the disease development, particularly at wet foliage or soil, high humidity, and poor air circulation.

There are also functional (teratological) diseases. Teratological diseases are abnormalities of physiological development.

4.2. Fungi as the main pathogens of diseases of woody plants

Fungi belong to the kingdom of *Fungi* (*Mycota*). There are more than 100 thousand species of fungi, including about 10 thousand plant pathogens (phytopathogens). A chitin in cell walls places fungi in a different kingdom from plants, bacteria, and other ones. As animals, fungi are heterotrophs. It means that they cannot produce their own food, instead taking nutrition from other sources of organic carbon, mainly plant or animal matter. They are secreting digestive enzymes into the environment. Fungi do not have chlorophyll in their cells and do not photosynthesize.

All fungi, like other living organisms, are described, grouped, and systematized. The division of fungi into groups is called the taxonomy of fungi. The knowledge of fungi taxonomy gives us the ability to identify the causative agent of plant diseases and justify measures to protect against it. Correct description of phytoparasitic microorganisms, their only names in Latin help in communication between phytopathologists of different countries.

FUNGI TAXONOMY (Fig. 4.3): KINGDOM → DIVISION → CLASS → ORDER → FAMILY → GENUS → SPECIES.

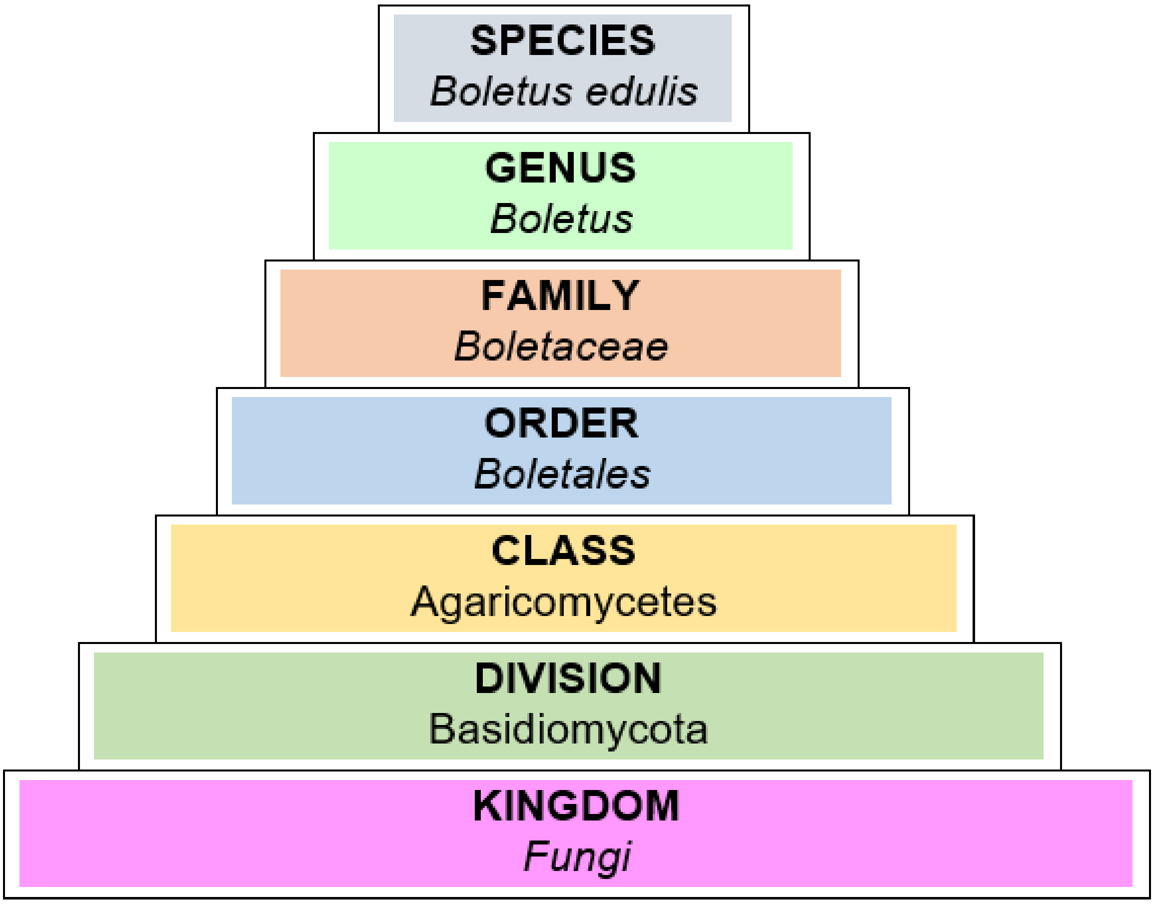

Fig. 4.3. Fungi taxonomy (*Boletus edulis* Bull.)

Fungi are eukaryotic organisms that have complex cellular structures, which consists of the nucleus, complex structure of internal membranes, and organelles (mitochondria, Golgi apparatus, endoplasmic reticulum).

Fungi are saprotrophs that live on fallen leaves, wood, humus and feed on the organic matter of the remains of dead plants and animals. Fungi live on or near their food source. Examples include mushrooms, molds and yeasts. Fungi have their own main role in nature – the mineralization of organic matter. Settling on the remains of plants or animals, they perform an important sanitary function in the cycle of substances in nature.

Depending on fungi appearance, they are divided into two large groups: micromycetes and macromycetes

Micromycetes are fungi such as molds, mildews and rusts. They have microscopic spore-producing structures. Micromycetes are distinguished from macromycetes by the absence of a multicellular fruiting body. They are ubiquitous in all terrestrial and water environments. Most of the fungal body consists of microscopic threads (hyphae). They extend through the substrate in which it grows. The mycelia of micromycetes produce spores that are carried by air and spread the fungus.

Fungi, which have dense plexuses of mycelium, stroma and fruiting bodies that are visible to the human eye, are called macromycetes. A mushroom is the fleshy, spore-bearing fruiting body of a fungus that is usually produced on the ground, in the soil, or other food sources.

According to the nutrition, all species of fungi are divided into:

- saprotrophs,
- parasites,
- mutualists.

A saprotroph is an organism that obtains its nutrients from non-living organic matter absorbing soluble organic compounds. It is usually dead plant or animal matter, which is decaying.

Saprotrophic nutrition has fungi, such as *Lentinula edodes* (Fig. 4.4) and *Pleurotus ostreatus* (Fig. 4.5). They decompose dead plant tissue by releasing enzymes from their hyphal tips.

Fig. 4.4. *Lentinula edodes*

Fumago vagans is a nonpathogenic fungus that grows on the honeydew (excrements) of scale insects (Fig. 4.6). *Fumago vagans* causes little damage to plants. It is an aesthetic problem. In the case of very heavy fungal coverings, the photosynthesis is impossible that cause plant decline.

Armillaria mellea causes root rot in many woody species and produces fruiting bodies around the base of trees (Fig. 4.7). The symptoms of infection appear in the crowns as discoloured foliage, reduced growth, branch dieback and death. Fruiting bodies are edible.

Fig. 4.5. *Pleurotus ostreatus*

Daedalea quercina frequently grows, causing a brown rot of oak (Fig 4.8). It prefers to grow on *Quercus* species, has also been found on *Fraxinus americana, Fagus grandifolia, Juglans nigra,* and *Ulmus americana.*

Thelephora terrestris is a saprotroph forming mycorrhiza on coniferous trees (Fig. 4.9). It is widely distributed in the forest on dry sandy soils, in forest nurseries, in the clear-cuts. Not being a parasite of plants, it can cause their death by enveloping seedlings of pine and other species.

Fig. 4.6. *Fumago vagans*

Fig. 4.7. *Armillaria mellea*

Fig. 4.8. *Daedalea quercina*

Fig. 4.9. *Thelephora terrestris*

Microsphaera alphitoides can be very severe on *Quercus robur* and *Quercus petraea,* particularly on young trees (Fig. 4.10). This disease can contribute to tree decline with other factors such as defoliation by insects. *Microsphaera alphitoides* decreases stomatal conductance. The infection makes the plants less shade tolerant.

Phellinus pini is a fungal plant pathogen that causes tree disease (Fig. 4.11). This disease, very common, renders the timber useless for industrial use. It causes a rot of the heartwood. Signs of the disease include wood destroing fungi protruding from the stems. Spores are blown by the wind and go on to infect other trees.

Fig. 4.10. *Microsphaera alphitoides*

Phragmidium disciflorum is common for the species of *Rosaceae* family (Fig. 4.12). This disease attacks all overground organs of the plants (shoots, leaves, buds, peduncles). The attack starts in spring, when yellow spots emerge on the superior side of the leaves. Orange formations emerge on the inferior side of the leaves.

Fig. 4.11. *Phellinus pini*

Fomes fomentarius is a fungal plant pathogen, which produces very large polypore fruit bodies (Fig. 4.13). It causes rot and grows on the trunk of various tree species. It infects trees through broken bark. The species typically continues to live on dead trees.

Fig. 4.12. *Phragmidium disciflorum*

Fig. 4.13. *Fomes fomentarius*

Mutualism is an interaction between two species, in which both have benefits. Mutualistic fungi are harmless to other living organisms. *Mycena pura* is widely distributed fungus (Fig. 4.14, 4.15). It decomposes forest litter under conifers (and occasionally under hardwoods).

Fig. 4.14. *Mycena pura*

Fig. 4.15. Fruit bodies of *Mycena pura*

Fungi structure. The mature fruiting body of the mushrooms have various structure. Most fungi are multicellular. The fruiting body is called the sporocarp. It is a multicellular structure on which spore-producing organs are formed. The mushroom contains a cap, a stem, and gills (Fig. 3.16). Many mushrooms produce spores on their gills, which are under a cap. The spores fall off the gills in a powder and travel some distance due to wind, and animals before landing. The life cycle of the mushroom begins again.

The fungal body has long thread-like structures called hyphae. Hyphae cluster together and make a mesh-like structure termed mycelium that grows underground.

The fruiting body exists for a short time of the fungi’s overall lifespan. However, the mycelium of a mushroom can live for a long time.

A mycorrhiza is a symbiotic association between a fungus and a plant. Some mycorrhizae produce reproductive bodies, for example mushrooms. The mushrooms provide nutrients to the tree, while the tree provides carbohydrates and a place for the fungus to reproduce.

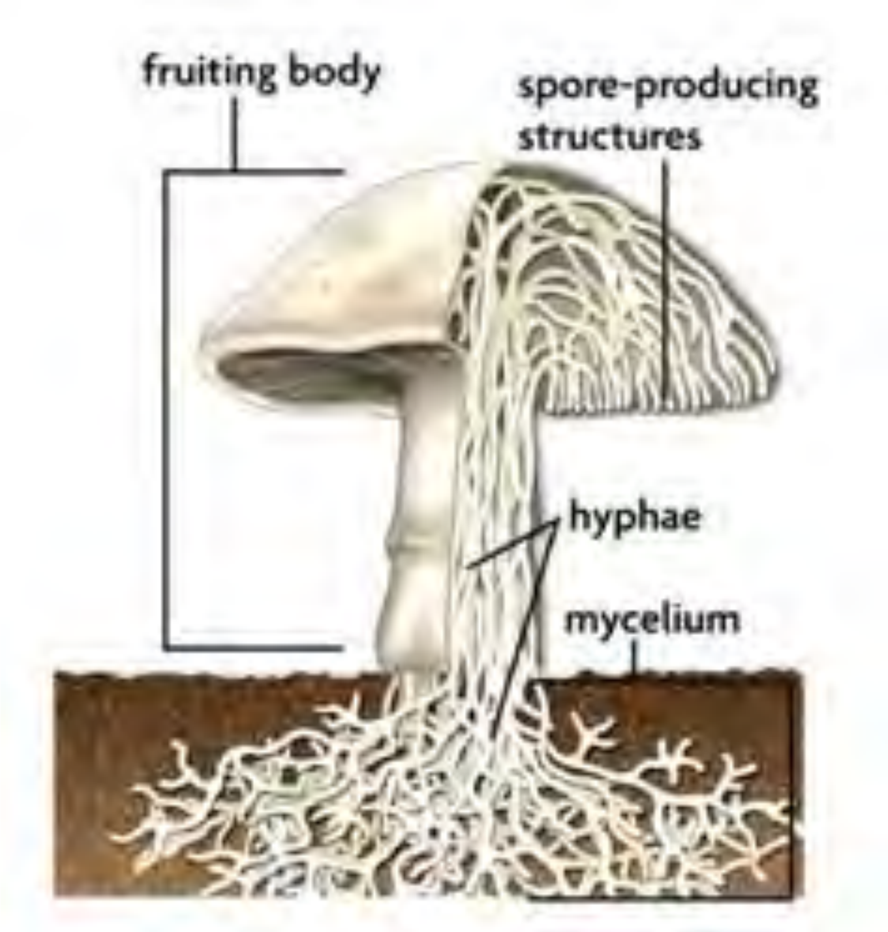

Fig. 4.16. Fungi structure [14]

4.3. Bacteria of woody plants

Bacteria are microscopic, unicellular, prokaryotic organisms. They may be variably shaped: spherical, rod-like, spiral, mycelial, or pleomorphic Bacterial leaf spots and blights, shoot blights and cankers can be harmful to woody species. However, generally bacterial diseases are not common in the forest.

BACTERIA TAXONOMY (Fig. 4.17): DOMAIN → DIVISION → CLASS → ORDER → FAMILY → GENUS → SPECIES.

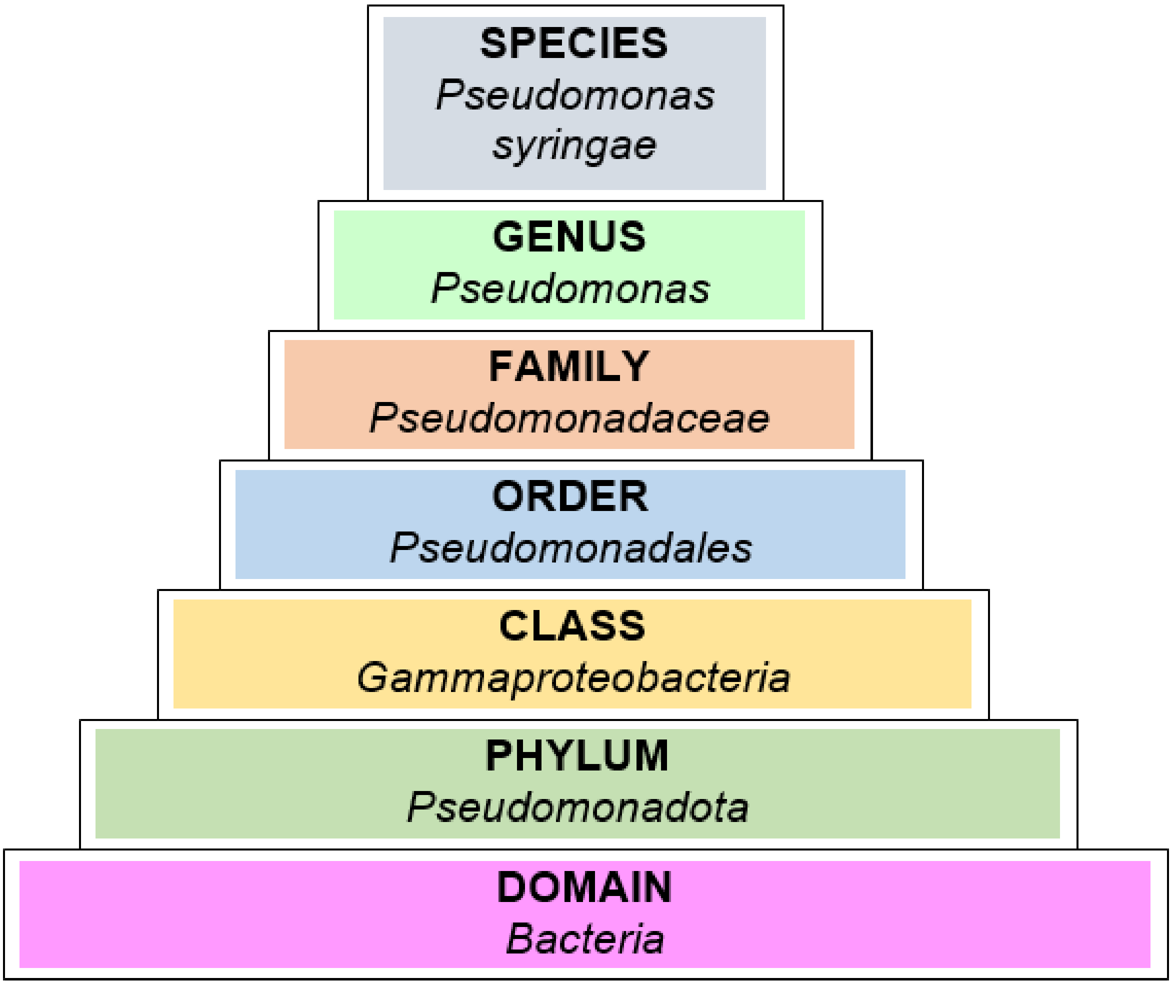

Fig. 4.17. Bacteria taxonomy (*Pseudomonas syringae* Van Hall.)

Pseudomonas syringae is a rod-shaped bacterium with flagella (Fig. 4.18, 4.19). As a plant pathogen, it can infect a wide range of woody species. It is named after *Syringa vulgaris*, from which it was first isolated.

Pseudomonas syringae overwinters on infected plant tissues or in healthy-looking plant tissues. In the spring, rain or other sources wash the bacteria onto leaves or blossoms where it grows throughout the summer. Once *Pseudomonas syringae* enters the plant through a leaf's stomata (necrotic spots on leaves, woody tissue) then the disease start.

Fig. 4.18. *Pseudomonas syringae*

Fig. 4.19. *Pseudomonas syringae*

The pathogen grows in intercellular space causing the leaf cankers and spots. *Pseudomonas syringae* can also survive in temperature slightly below freezing. The below-freezing temperatures increase the severity of infection within trees like apricot, cherry, and peach.

Pseudomonas radiobacter var. tumefaciens is a soil bacterium pathogenic for plants of the genus *Rhizobium*. It causes the formation of galls in plants (Fig. 4.20, 4.21). They are straight or slightly curved rod-shaped bacteria. They do not form spores, are motile, have 1–4 flagella.

Fig. 4.20. *Pseudomonas radiobacter var. Tumefaciens*

Fire blight (fireblight), is a contagious disease affecting apples, pears, loquat, quinces, hawthorn, cotoneaster, pyracantha, raspberry and other members of the family *Rosaceae*. The causal pathogen is a bacterium *Erwinia amylovora*. It is a short rod with rounded ends and many flagella.

Erwinia amylovora overwinters in cankers formed during the previous season. Warmer temperatures in the spring support development. Bacteria-filled ooze begins to exude from the cankers. Birds and insects are attracted to this ooze and they can spread bacteria. Rain and wind can also transmit the bacterium. *Erwinia amylovora* can enter the plant through the stomata.

Fig. 4.21. *Pseudomonas radiobacter var. tumefaciens*

4.4. Virus diseases of woody plants

Viruses often infect woody plants like grapevine, fruit trees and ornamental plants. The virus spreads mainly with the juice of a diseased plant. Infection carriers are often sucking insects. Infection can occur through tools, knives and secateurs.

It is possible to suspect that a tree is infected with a viral infection in the presence of such signs as a violation or stunting of the plant, the appearance of mosaicism and a change in leaf color, which can subsequently lead to its drying out and death.

The main types of viral diseases of trees and shrubs are mosaic, variegated, and wilting.

When viral diseases affect woody species, trees' assimilative capacity, growth, flowering and fruiting, resistance to diseases and winter hardiness of plants decrease, and their ornamentality and quality deteriorate.

4.5. Interaction of plants, fungi, bacteria, viruses and their role in ecosystems

Due to genetic variability, modified pathogens emerge. They sometimes have new pathogenic properties and are able to affect plants resistant to old pathogens. At the same time, new varieties of host plants appear. Some of them are more resistant to pathogens.

Among the new pathogens and the new host plants, those that are more effective usually survive. The less effective ones usually die due to selection.

The disease develops only when the virulent pathogen falls on a susceptible host. The disease does not develop if pathogens are not virulent or the host is resistant.

The situation may change under the influence of external factors. Plant resistance, which is quite effective under normal conditions, may be overcome by the pathogen when conditions are favourable for it and unfavourable for the host plant.

The ending result of the interaction of the pathogen and the host depends on the comparative characteristics of the mechanisms of infection and protection. Variability of host plants is due to hybridization and mutations. In fungi, these mechanisms are more diverse. They include mutations, parasexual combinations, hybridization, and adaptation.

Plant resistance to pathogens often dominates, susceptibility and virulence of pathogens is a recessive trait. That is why most plants are immune to most pathogens. As a result, the range of most pathogens' hosts is limited.

4.6. Common diseases of woody plants

Below are the most common diseases of woody plants and their causative agents.

Diseases of fruits and seeds of woody plants. The widespread pathogen species are *Stromatinia pseudotuberosa*, *Sclerotinia betulae*, *Monilia fruectigena, Marssonina juglandis, Gnomonia leptostyla.*

Pathogens of the disease from the genus *Cytospora* on poplar, oak, hornbeam, linden, birch, and spruce lead to the appearance of dry tops, dying branches or the entire tree.

Fruit and seed mold is caused by pathogens of the genera *Penicillium*, *Aspergillus*, *Trichothecium*, *Botrytis*, *Rhizopus*. Seeds of almost all deciduous and coniferous tree species and juicy fruits are affected. A characteristic feature of mold is its color. Infection with mold fungi occurs when seeds and fruits are damaged by insects, improper storage, or during transportation.

Diseases of seedlings. Young plants grown in nurseries are very sensitive to infectious diseases. Minor damage can lead to drying out or damage by pathogens. Pathogens of seedlings affect stems, roots, leaves, needles, and cotyledons. Seedlings suffer from *Thelephora terrestris, Colletotrichum gloeosporoides, Venturia tremulae, Phytophtora omnivora, Rosellinia quercina, Fusticladium radiosum.*

The causative agents of fusariosis in most cases are fungi of the genus *Fusarium*, rarely *Pythium*, *Rhizoctonia* and *Alternaria*.

Diseases of needles and leaves of woody plants. The most common diseases are *Lophodermium pinastri, Leptostroma pinastri*, *Microsphaera alphitoides, Apiosporum pinophilum*, *Hormiscium pinophilum, Apiosporum salicinum*, *Fumago vagans* and causative agents of the genus *Coleosporium.*

Necrotic, vascular and cancer diseases of branches, trunks of woody plants. Diseases of branches and trunks are very diverse. They affect woody plants of different ages. Necrotic and vascular diseases are very common among them.

The consequence of these diseases is the death of individual branches and dry tops of trees. Some diseases can cause the death of individual trees or entire stands. They are *Melampsora pinitorqua, Cenangium abietis*, *Dothichiza ferruginosa*, *Nectria cinnabanina, Tubercularia vulgaris, Clithris quercina*, *Ceratocystis ulmi, Ceratocystis roboris*, *Ceratocystis valachicum, Ceratocystis quercus, Cronartium flaccidum*.

"Witches' broom", flower parasites and hemiparasites. The term "witches' broom" relates to the deformity of branches in trees. They can be small or large, and a single tree may have several or only one such brooms. The causative agent is of unknown etiology. It causes the deformation of branches in the form of bends and "witches' brooms", causing at the same time the intensive development of dormant buds or the formation of additional buds. It is often found on maple, hornbeam, beech. "Witches' brooms" are formed on the branches, and sometimes on the trunks.

Viscum album is a hemiparasite on several tree species, from which it draws water and nutrients. It is an evergreen shrub, which grows on the stems of trees. It has stems 30–100 cm. The fruit is a white or yellow berry. It is commonly found in the crowns of broad-leaved trees, particularly apple, maple, linden, hawthorn and poplar.

Viscum austriacum is parasitic on pine. It differs from white mistletoe by narrow, long leaves, and has yellowish fruits.

Lathraea squamaria is a shade-tolerant, herbaceous, perennial plant. It is parasitic on the roots of hazel, alder, birch, beech, hornbeam, spruce, aspen, linden, and other woody plants. The plant is reddish-white, 8–25 cm tall, with a long branched rhizome. It reproduces by seeds that are carried by the wind and insects. The development of it on the roots of woody plants leads to a strong weakening of these trees and a sharp decrease in productivity. It is also able to regenerate from broken fragments of the underground stem.

Rots of woody plants. Among the causative agents of rot can often be found the next. *Phellinus pini* often affects Scots pine, but it can develop on Pseudotsuza, larch, fir, yew, cedar. *Phellinus pini* affects 40–50-year-old trunks of spruce, occasionally pine, fir and larch. *Fomitopsis pinicola* occurs on dead or severely weakened trunks of spruce, other coniferous or deciduous woody species. *Fomes fomentarius* affects the trunks of beech, ash, aspen, birch, poplar, hornbeam, willow, alder, maple, cherry and many other deciduous species. *Phellinus igniarius* affects the trunks of many deciduous woody plants. *Laetiporus sulphurous* affects oak, larch, and other species. *Piptoporus betulinus* affects only birch trunks. *Daedalea quercina* affects old trunks of oak with mechanical damage, occurs on stumps of oak, chestnut and beech. *Heterobasidion annosum* affects Scots pine, spruce, Weymouth pine, fir, larch, sometimes occurs on the shore, aspen, aspen. *Armillariella mellea* occurs on more than 200 species of woody plants. *Phaeolus schwenitzii* causes pine rot. *Phaeolus schwenitzii* affects spruce, larch, Weymouth pine and cedar, fir, sometimes oak, hazel, cherry. *Agrobacterium tumefaciens* affects apple, pear, cherry, plum.

CHAPTER 5. WEEDS IN THE FOREST

5.1. The concept of weeds in forestry

The weeds in forestry are herbaceous plants, shrubs, and trees that, in forest nurseries, stands, and clear-cuts areas weaken or prevent normal forest crops growth. Most target tree seedlings grow slower than many weed species. Weeds in nursery can greatly reduce seedling output and their quality.

However, weeds in forestry are not always harmful and useless. Weeds prevent soil erosion. Herbaceous weeds in forest stands represent food or bedding for wild mammals and birds. Wood weeds can be a shelter for them. The fruits of some weeds can be edible. Some weeds are medicinal plants. However, the benefits of weeds, particularly in young forest stands, are significantly less than the damage caused and the forestry management has some problems to deal with when it comes to weeds.

Forest nurseries and stands have ideal places of floristically rich and diverse weed flora. Weeds well adapt to environmental conditions due to high seed production and the great possibility to expansion. The weed species composition and spread depend mainly on climate factors and geographic region. The soil physical and chemical properties are also important for weeds. Weeds compete with trees for water, nutrients and light.

As a result, trees grow slowly, sometimes a significant number of trees die. Effective weed control usually requires using of herbicides. Weed control can be a never-ending task. Therefore, weed control is essential during a planted forest's establishment phase. This time is about the first three years after planting.

5.2. Weed classification

Compared to cultivated plants, weedy plants have considerable fitness to numerous ecological factors. The most important weed trait is the expressed adaptation ability.

Weeds have the pronounced resistance to unfavourable environmental conditions (poor soil, drought, moisture, wind, etc.). Huge amounts of weeds are resistant to plant diseases and pests.

Another weed trait is the periodicity of germination. Weeds produce an enormous quantity of seeds, which makes it easier for them to spread in space. Often weed seeds germinate in different time periods. Therefore, it is hard to control weeds simultaneously. Wind, water, animals, and man can spread weed seeds. Weeds can be as native and or introduced plant species.

There are about 30000 species under world conditions. They are grouped as based on:

1. Life span (annual and perennial);
2. Ecological affinities (wetland, garden land, dry lands weeds);

3. soil type (weeds of black cotton soil, red soils, light, sandy or loamy soils, laterite soils, weeds that occur in soils having good drainage);

4. Place of growing (weeds of croplands, pasturelands, waste places, forests, roadsides).

5. Origin (indigenous weeds, introduced or exotic weeds);

6. Cotyledon amount (monocots and dicots);

7. Soil pH (acidophile, basophile, neutrophile weeds of neutral soils);

8. Morphology (grasses, sedges, broad-leaved weeds);

9. Nature of stem (woody, semi-woody, herbaceous weeds);

10. Specificity (poisonous, parasitic, aquatic weeds).

Often weeds are divided into two main groups in forestry:

- annual weeds;
- perennial weeds;
- woody weeds.

Annual weeds grow, flower and release their seeds in one year. The parent plant dies in autumn but only after it has spread seeds. Examples of annual forest weeds are *Amaranthus retroflexus* L. (Fig. 5.1), *Ambrosia artemisiifolia* L. (Fig. 5.1), *Anisantha tectorum* (L.) Nevski, *Apera spica-venti* (L.) P. Beauv. Annual weeds are small herb plants, which have shallow roots and weak stems.

Fig. 5.1. Amaranthus retroflexus L. [15]

Perennial weeds come back every year and can live indefinitely. Examples of perennial weeds: *Acorus calamus* L. (Fig. 5.3), *Asclepias syriaca* L., *Cichorium inthybus* L. (Fig. 5.4), *Helianthus tuberosus* L. They spread not only through seeds but also by root, underground stem, rhizomes, tubers.

Woody weeds usually mean invasive tree species. Examples of woody weeds are *Acer negundo* L. (Fig. 5.5), *Ailanthus altissima* (Mill.) Swingle, *Fraxinus ornus* L., *Fraxinus pennsylvanica* Marshall, *Quercus rubra* L. (Fig. 5.6), *Robinia pseudoacacia* L., *Salix fragilis* L., *Ulmus pumila* L.

Fig. 5.2. Ambrosia artemisiifolia L. [16]

Fig. 5.3. Acorus calamus L. [17]

Fig. 5.4. Cichorium inthybus L. [18]

An invasive plant is a species (annual, perennial, woody) that grows aggressively, spreads, and displaces other plants. Invasive weed species can spread and invade new habitats. Invasive plants are mostly introduced species or "nonnative" that can degrade the habitats. Introduced species were brought from other countries. They are normally troublesome and control becomes difficult.

Four stages of invasion are identified:

- introduction,
- naturalization,
- colonization,
- dispersal.

Fig. 5.5. Acer negundo L. [19]

Fig. 5.6. Quercus rubra L. [20]

5.3. Highly invasive plant species of Ukraine

Invasive plant species pose a global threat to the environment, as they have a negative impact on the ecological, economic and socio-political situation on a global scale.

Invasive plant species can pose severe threats to biodiversity and stability of native ecosystems. Biodiversity protection includes the detection of invasions, ways of their spread, control or destruction of particularly dangerous invasive plant species, and prevention their spreading and rooting.

An extensive networks of complex studying, mapping, forecasting risks, and management of valuable natural resources territories, taking into account possible invasions were created in European countries. The increase in the number of invasive species prompts the identification of species with the highest invasive potential. Below there is a list of invasive species that pose the greatest threat to the environment, economy, including agriculture, and human health.

List of invasive plants [35]:

Acer negundo L.

Acorus calamus L.

Ailanthus altissima (Mill.) Swingle

Amaranthus albus L.

Amaranthus blitoides S. Watson

Amaranthus retroflexus L.

Ambrosia artemisiifolia L.

Amelanchier spicata (Lam.) K. Koch

Amorpha fruticosa L.

Anisantha tectorum (L.) Nevski

Apera spica-venti (L.) P. Beauv.

Arrhenatherum elatius (L.) J. Presl et C. Presl

Artemisia annua L.

Asclepias syriaca L.

Azolla caroliniana Willd.

Azolla filiculoides Lam.

Bidens frondosa L.

Bupleurum fruticosum L.

Capsella bursa-pasroris (L.) Medik.

Cenchrus longispinus (Hack.) Fernald

Centaurea diffusa Lam.

Cichorium inthybus L.

Conyza canadensis (L.) Cronq.

Echinocystis lobata (Mixch.) Tor. et A. Gray

Elaeagnus angustifolia L.

Elodea canadensis Michx.

Fraxinus ornus L.

Fraxinus pennsylvanica Marshall

Galinsoga parviflora Cav.

Galinsoga urticifolia (Kunth) Benth.

Grindelia squarrosa (Pursh) Dunal

Helianthus tuberosus L.

Heracleum mantegazzianum Sommier et Levier

Heracleum sosnowskyi Mandem.

Impatiens glandulifera Royle

Impatiens parviflora DC.

Iva xanthiifolia Nutt.

Lepidium densiflorum Schrad.

Lepidotheca suaveolens (Pursh.) Nutt.

Lupinus polyphyllus Lindl.

Oenothetra rubricaulis Klebahn

Oenothetra depressa E. Grene

Padus serotina (Ehrh.) Ag.

Partenocissus inserta (A. Kern.) Fritsch.

Phalacroloma annuum (L.) Dumort.

Phalacroloma septentrionale (Fernald et Wiegand) Tzvel.

Portulaca oleracea L.

Quercus rubra L.

Symphyotrichum salignum (Willd.) G.I. Nesom

Reynoutria japonica Houtt.

Rhamnus alaternus L.

Robinia pseudoacacia L.

Rudbeckia laciniata L.

Salix fragilis L.

Senecio cineraria DC.

Senecio viscosus L.

Setaria pumila (Poir.) Roem. et Schult.

Setaria viridis P. Beauv.

Solidago canadensis L.

Ulmus pumila L.

Vicia villosa Roth.

Xanthium albinum (Widd.) H. Scholz

Xanthoxalis dillenii (Jacq.) Holub

Xanthoxalis stricta (L.) Small.

5.4. Weed control in forestry

There are numerous measures and procedures for weed control in forestry. In order to control weeds successfully, we should use different care and control measures. There are several methods of weed control: preventive, mechanical, physical, mulching, biological, cultural, and chemical control.

Preventive measures. The main purpose of preventive measures is to prevent weed spread. Preventive measures in forestry weed control include:

- sowing only pure crop seeds;

- weeds killing in forest nurseries and 2–4-years old plantations;

- prevention the spread of weed seeds by keeping forest machinery and objects clean;

Mechanical measures. Mechanical measures against weeds include such treatment as ploughing, disking, tilling, etc. Hoeing and weeding are carried out during the vegetation period in forest nurseries.

Mowing is the most popular way of suppressing the already growing weeds and preventing their spread. Multiple repetitions of mowing make plant exhaust and mortality. The pruning of stem and stump shoots is another method of weed suppression in forestry. However, this weed suppression method is ineffective and relatively expensive due to intense labour.

Different specialized machines and hand tools are used in forest vegetation management. Disks and plows are also sometimes used. Saws, axes, powered brush cutters, hatchets can be used in weeding operations. Mechanical control is not suited to all places. Mechanical vegetation management is not used in unsuitable terrain, when high likelihood of soil erosion, and operating costs.

Mulching. Mulching is the covering of soil with a variety of materials such as sawdust, stubble, straw, polyethylene film, and others, to prevent weed growth. This method is utilized in smaller areas, in forest nurseries. This way of weed control is efficient for annual weeds but is not useful for perennial weeds.

Physical measures. Physical weed control measures include the use of flame and superheated steam. The use of flame for weed killing is the most effective at the end of vegetation. In this way, it is possible to destroy most weed seeds that are spread on the soil surface. Burning weeds is carried out often as a method of preventing forest fires. Destruction of weeds using steam is applied in forest nurseries during the preparation of substrates for sowing or planting. This sterilization kills not only weed seeds but also plant pathogens and insects.

Biological control. This control is based on the application of natural agents, which are weed enemies such as fungi, insects, viruses, and bacteria. They prevent of weed spreading.

Cultural Control. Cultural weed control includes those practices that favour the desired species and make them more competitive with weeds. It could be selection of the best adapted species, thorough site preparation, planting of vigorous, healthy, large seedlings, planting of seedlings at the appropriate spacing and replacing those plants that die.

Chemical control. Using herbicides is the main part of chemical control. Herbicides are used in forestry to manage the composition of tree species, reduce competition from shrubs and herbaceous vegetation, as well as to control invasive species. Using of herbicides to control competing vegetation can increase wood volume yields by 50–150 % in young forests.

Applying the right amount of the most effective herbicides at the right time is the best way to control weeds in forests.

All weed treatment alternatives, their effectiveness and potential environmental impacts are listed in table 5.1.

Forest management should not negatively affect soil, water and biodiversity. Herbicides should be used in ways that minimise risks to the environmental changes.

The best cultural, mechanical, biological and chemical practices in forest management systems should be integrated to minimize losses and detrimental effects due to weeds.

All weed control practices should be aimed at growing the target tree species in forests. Vegetation management is a primary goal to achieve a productive forest.

Table 5.1. Treatment alternatives for different weed types

Weed types	Treatment alternatives	Effectiveness	Potential environmental impacts
Perennial weeds	herbicides	Very effective	They can be potential pollutants depending on the environment in which the herbicide occurs (water, soil) and the applied herbicide
	cutting	Not effective	No adverse effect on the environment
	cultivation	Effectiveness varies with weed and site	
	mulching	Not effective	
Annual weeds	herbicides	Very effective	They can be potential pollutants depending on the environment in which the herbicide occurs (water, soil) and the applied herbicide
	cutting	Effective	No adverse effect on the environment
	cultivation	Very effective	
	mulching	Effectiveness varies with weed and site	
Bracken	herbicides	Very effective	They can be potential pollutants depending on the environment in which the herbicide occurs (water, soil) and the applied herbicide
	cutting	Low effect	No adverse effect on the environment
Woody weeds	herbicides	Very effective	They can be potential pollutants depending on the environment in which the herbicide occurs (water, soil) and the applied herbicide
	cutting	Low effect	No adverse effect on the environment

CHAPTER 6. INTEGRATED PEST MANAGEMENT

According to the Law of Ukraine “On Plant Protection”, “... integrated pest management (IPM) is a complex application of methods of long-term regulation of the development and spread of harmful organisms to an acceptable economic level based on forecasting, economic thresholds of harmfulness, the action of beneficial organisms, energy-saving and environmental protection technologies that ensure reliable protection of plants and ecological balance of the environment...”.

The outbreaks of forest pests often cover many thousands of hectares of forest stands. If protective methods are not taken at the right time, the outbreak area will cover a large forest area. The outbreaks of foliage-browsing insects are cyclic and occur every 9–12 years, depending on pest species, region, and weather conditions. The outbreaks of stem pests mainly depend on the forest’s health and the proportion of weakened trees. The outbreaks of seed pests depend on seed amount, and outbreaks of the pests of regeneration depend on the area of unclosed plantations.

However, unlike agriculture, the products of which are obtained annually, the main product of the forest - wood - is often obtained decades after damage by insects or diseases, sometimes repeatedly. However, under favorable conditions, the health condition of the trees and the rate of wood increment is gradually restored.

In this regard, forest protection measures should be applied if they are able to prevent forest damage above economically dangerous levels, and not be applied at all if they are not economically or ecologically proven.

Contemporary forest protection is based on the integration of various methods that lead to the reduction in infestation and limit the damage caused by insects or pathogens.

The concept of integrated pest management (IPM) appeared in the 1970s. Accordingly, the goal of integrated forest protection (IFP) is not the struggle against individual harmful organisms (insects, pathogens, weeds), but the sustainable reduction of their populations to an economically acceptable level through various measures and methods based on considering ecosystem relationships and population dynamics of harmful and beneficial organisms.

The choice of IPM tactics depends on the possible level of economic and other losses, and sometimes the ecological, recreational, or aesthetic functions of forest ecosystems may be more important than their role as a source of wood or other raw materials.

A large group of active substances that could be dangerous for humans or the environment is forbidden. In 2009, two legal acts were issued that influenced the legal environment in plant protection and plant protection product availability in all the

European Union Member States: Directive 2009/ 128 and Regulation 1107/2009. These legal acts brought a number of changes, but the most significant is the ban on aerial spraying introduced by Directive 2009/128 (Article 9) and the improvements of some registration procedures by Regulation 1107/2009 - the obligatory implementation of integrated pest management in the European Union from January 2014.

The ban on aerial spraying is not total. Aerial spraying may be allowed when there are no viable alternatives (as in the protection of mature forest stands), the products used are explicitly approved for aerial spraying, the area to be sprayed is not in close proximity to residential areas, and the competent authority issues approval of the aerial spraying plan (based on a request with information about the provisional time of spraying and the amounts and type of plant protection products applied). However, the necessity of obtaining approval from the competent authority may theoretically result in a decrease in aerial applications of plant protection products in forests, for example, in cases when the need for application is very urgent and the application makes no economic sense after the time necessary to obtain permission.

The improvements to registration procedures by Regulation 1107/2009 resulted in the facilitation of the registration process. The provision of Regulation 1107 enables an extension of the authorization of a registered plant protection product for minor uses, which is relatively simple. This enabled an increase in the availability of plant protection products registered for use in forests in 2018.

The main blocks of the IPM system include:

– forest pathological monitoring;

– accumulation and analysis of information;

– forecast of forest damage and the consequences;

– decision-making;

– preventive (establishment measures);

– operational measures (chemical, biological, etc.);

- control over the consequences of such measures;

– adjustment of forecasting and decision-making.

According to this, the first stage for the implementation of the IPM strategy is the assessment of the ability of organisms to cause damage, which is implemented in the system of forest pathology monitoring, or in the system of survey, and assessment (Chapters 7, 8), and forecasting of forest pests (Chapter 9).

The second stage of the implementation of the IPM strategy is the improvement of the system of preventive and active forest protection measures, including quarantine, physical-mechanical, chemical, and biological ones, and most importantly, increasing the stability (resistance) of forests, reducing the negative impact of man-made pollution, recreation, fires, forest management activities, etc. These blocks are considered in Chapters 10–13.

CHAPTER 7. TREE HEALTH ASSESSMENT

Under the influence of harmful organisms, crown density decreases, foliage is partially lost or insufficiently developed, the wood growth and quality decreases, and the crops and quality of cones, fruits, and seeds deteriorate.

A variety of activities of harmful organisms are reflected in the crown's appearance. “Sanitary Forest Regulations in Ukraine” contain a universal scale for identifying the category (class) of the health condition of trees. The health condition of each tree is evaluated on a range of visual characteristics according to the following classes: I – healthy; II – weakened; III – severely weakened; IV – drying up; V – recently died and VI – died over a year ago (Tables 7.1, 7.2). The health condition index (HCI) is calculated as a weighted average of the trees in each class of health condition.

However, additional indicators must be taken into account when diagnosing the causes and predicting the consequences of tree damage or infection. These indicators reflect the specific reactions of individual forest tree species to damage or infection, for example, the level of defoliation, leaf discoloration, crown structure change, stem damage, symptoms and signs of various biotic, abiotic, or anthropogenic factors.

Symptoms of the damage are changes or disturbances of a tree or its parts, which affect the ability of a tree (or its part) to perform vital functions (photosynthesis, transfer of moisture and nutrients to the crown) and lead to the weakening of trees, a decrease in growth, deterioration in wood quality, and sometimes to dieback. Examples of symptoms are the loss or change in the foliage color, wounds, necrosis, and ulcers on certain parts of the plants, their deformation, or drying up.

Unlike symptoms, which are manifested in a change in the condition of a tree or its individual organs, the *signs* are a direct manifestation of harmful organisms that have caused tree damage.

Examples of signs are the fruiting bodies, mycelium, spores of fungi, nests of insect larvae, molting skins, excrements, galleries, etc., as well as specific plant damage (skeletonization, twisting, leaf mines, galleries under the bark, in wood, shoots, and roots).

Information about the trees' health condition and possible reasons for their deterioration is obtained during the survey. Various specific methods are used for certain pests, taking into account their biology (pheromone traps, trapping belts, trees, etc.).

The survey is carried out primarily in the stands with a high risk of damage by wind, and fire, after selective felling, on the border with clear-cuts and burnt areas, in existing and potential foci of pests and diseases.

Thus, pure stands (or with 9 units of host tree species in the stand composition) with a low relative density of stocking (0.4–0.5), and an age of 20–50 years are the most attractive for pine foliage-browsing insects.

7.1. Characteristics of coniferous trees of various health condition [Sanitary Forest Regulations in Ukraine]

Health condition class	Indicators of tree condition
I – healthy	Dense crown, green silvery needles; current year growth is of normal size for this tree species, age, season, and growing conditions: stems and superficial roots have no external signs of damage.
II – weakened	Sparse crown, green or light green needles, scorched not more than 1/3, the increment is decreased not more than 1/2, the drying out of some branches, the damage of some superficial roots, local stem damage.
III – severely weakened	Very sparse crown, light green or opaque needles scorched not more than 1/3, the increment is very low, the drying out not more than 2/3 of crown size, damage of stem and superficial roots not more than 2/3 of the perimeter, attempts of colonizing or local colonizing by stem pests, fruiting bodies or other signs of wood destroying fungi on the stem and superficial roots.
IV – drying up	Very sparse crown, yellowish or yellow-green foliage that falls off; very low or absent increment; drying out more than 2/3 of crown size; damage of stem and superficial roots more than 2/3 of the perimeter; colonizing by stem pests.
V – recently died	Foliage is gray, yellow, or red-brown, partially falling off; partial bark loss; colonizing by stem pests or their exit holes.
VI – died over a year ago	Living foliage is absent, bark and small twigs falling off, and the mycelium of wood-destructive fungi under the bark.

7.2. Characteristics of deciduous trees of various health condition [Sanitary Forest Regulations in Ukraine]

Health condition class	Indicators of tree condition
I – healthy	Dense crown, green foliage; current year growth is of normal size for this tree species, age, season, and growing conditions; stems and superficial roots have no external signs of damage.
II – weakened	Sparse crown, leaves fall prematurely; the increment is decreased not more than ½; the drying out of some branches; local damage of stem and superficial roots; single epicormic shoots.
III – severely weakened	Very sparse crown, very small leaves, light green, turn yellow and fall prematurely; the increment is very low or absent, the drying out 2/3 of crown size; damage of stem and superficial roots is on 2/3 of the perimeter; sap secretion from stem and limbs; colonizing by stem pests; numerous epicormic shoots; fruiting bodies or other signs of wood destroying fungi on the stem.
IV – drying up	Drying out more than 2/3 of crown size; damage of stem and superficial roots more than 2/3 of the stem perimeter; colonizing by stem pests; drying epicormic shoots.
V – recently died	Foliage is dry, withered, or absent; partial bark loss; colonizing by stem pests or their exit holes.
VI – died over a year ago	Living foliage is absent; bark and small twigs falling off; the mycelium of wood-destructive fungi under the bark.

During the survey, the health condition of trees, the causes of their damage, their distribution, and their severity are assessed.

Crown condition is estimated by defoliation, the proportion of dry branches, and epicormic shoots. Defoliation is estimated visually as a percentage, and either used in the analysis directly or converted into points, depending on the task of the survey and the factor being evaluated.

For example, in the foci of foliage-browsing insects, the defoliation level is estimated on a uniform scale after the end of larval feeding:

1 point – below 25 %; 2 points – 26–50 %; 3 points – 51–75 %; 4 points – above 75 %.

After the completion of the survey, the area of stands is evaluated, which is necessary to treat with insecticides. These are stands where defoliation exceeded 25% for coniferous and 50% for deciduous.

The stands sometimes worsen their health condition not as a result of direct insect damage but as the result of insufficient foliage formation or premature fall (for example, due to technogenic pollution). In such stands, defoliation is assessed in July-August (before the older needles turn yellow and fall off), and in the analysis, the defoliation is expressed in accordance with the recommendations of the ICP Forests monitoring program:

– 0 points – undamaged (below 10 %);

– 1 point – slightly damaged (11–25 %);

– 2 points – moderately damaged (26–60 %);

– 3 points – severely damaged (over 60 %).

The discoloration is estimated by the same ranges.

It gives the possibility to compare the data from different regions, particularly after forest damage by abiotic factors or chronic diseases (verticillosis, root rot, ash dieback, Dutch elm disease, etc.).

The proportion of dry branches in the crown is also assessed visually in per cents, and then converted to points:

– 0 points – absent;

– 1 point – до 10 %;

– 2 points – 11–50 %;

– 3 points – 51–75 %;

– 4 бала – over 75 %.

Such ranges are used to estimate the ash dieback severity and can be also used for predicting the trends of health condition in the foci of other diseases.

The spread of epicormic shoots is also ranged by a scale:

– 0 points – absent;

– 1 point – single;

– 2 points – abundant;

– 3 points – completely covered stem.

The spread of epicormic shoots characterizes both the level of tree weakening and its ability to subsequently restore health.

Stem condition is assessed by the spread of necrosis, ulcers, hollows, cracks, and other disorders. In the foci of diseases, non-specific or simplified scales for assessing individual symptoms and signs are used.

Non-specific scale for stem assessing:

– 0 points – symptoms of diseases or damage are absent;

– 1 point – slight damage (a small number of cracks overgrown with callus, necrosis of the collar zone up to 25% of the perimeter);

– 2 points – moderate damage; wounds and cracks up to 5 cm long are not overgrown with callus, necrosis of the collar zone in 26–50% of the perimeter, traces of lightning, frost cracks;

– 3 points – severe damage; wounds and cracks over 5 cm long are not overgrown with callus, traces of lightning, frost cracks, rots, and collar necrosis in 51–75 % of the perimeter, fruiting bodies of wood-destroying fungi;

– 4 points – very severe damage; large wounds, rots, hollows, numerous fruiting bodies of wood-destroying fungi; collar necrosis over 75 % of the perimeter, the areas of peeling bark.

A simplified scale for assessing the spread of fruiting bodies of wood-destroying fungi:

– 0 points – absent;

– 1 point – single;

– 2 points – abundant.

A simplified scale for assessing the spread of ash cancer (tuberculosis):

– 0 points – absent;

– 1 point – single;

– 2 points – abundant;

– 3 points – fully covered stem.

The rate of tree mortality is evaluated by the sum of the trees of the 5th and 6th classes of health condition. Such mortality is considered pathological if the diameter of the trees of the 5th health condition class exceeds the diameter of viable trees.

The cause of tree damage is identified by the characteristic symptoms, signs, and their localization (an organ, a stem part, etc.) and, if necessary, is specified by phytopathological laboratory analysis.

The results of the forest health assessment are used for forecast correcting and, if necessary, forest protection measures are prescribed.

CHAPTER 8. PEST SURVEY AND ASSESSMENT

8.1. Types of survey

For trustworthy decision-making in forest protection, several main questions must be answered:

– the cause of forest damage (pests, abiotic or anthropogenic factors);

– the prevalence of damage;

– the severity of the damage.

The prevalence of a certain damage type is estimated as the proportion of plants (trees or leaves) with the presence of such damage.

When analyzing the impact of environmental conditions at individual sites, or the impact of individual insects or pathogens, the prevalence of each type of damage is estimated as a percentage.

When summarizing the results of a survey, the prevalence of each type of damage is evaluated in points. For example, for unclosed plantations:

0 – no damage;

1 (low level) – up to 30% of plants are damaged;

2 (medium level) – more than 30 and less than 60% of plants are damaged;

3 (high level) – more than 60% of plants are damaged.

The severity of damage is described by a score, the scales of which depend on the damaged plant organ, and the type of damage, as well as the biology of certain insects or fungi (see chapter 7).

The severity of direct damage by foliage-browsing insects is assessed by defoliation level, which is evaluated with an accuracy of 10%.

The severity of damage by sucking pests and root damage is assessed indirectly by the change in the foliage color and size and the change in the health condition of the plant. The evaluation of other types of tree damage is described in Chapter 7.

Forest pathological monitoring (survey) is a system of permanent or periodic inspections and assessments for timely detection, and obtaining information on the spread and development of forest pests and diseases for timely planning and implementation of forest protection measures as needed.

The *General survey* includes the detection of cases of trees weakening, damage, or destruction by harmful organisms and other factors. It is carried out by all specialists and workers of forestry enterprises.

Special survey – includes timely detection of foci of certain pests or diseases, monitoring of existing foci and potential sites of their development.

The first symptoms and signs of forest damage must be detected by forest workers and reported to the forest enterprise. Such symptoms and signs are the increase of trees number with drying crowns, recent windbreak, premature leaf yellowing and fall; shoot breaking off; a local dying of trees or seedlings in the nursery; noticeable swarming of insects; the presence of egg masses, web nests on trees and undergrowth; the presence of larval excrements and leaf fragments on the soil; noticeable defoliation, twisting the leaves with cobwebs; chlorosis; sawdust on or under stems (signs of colonization by stem pests), etc.

Forest pathological *reconnaissance surveys* may be ground or remote (for example, using survey cameras). It is carried out for the urgent verification of signals on forest damage.

Forest pathological *detailed survey* is carried out at the permanent plots, where numerous parameters are assessed, particularly pests' population level, and vitality to know the trends of forest damage spread and development.

8.2. Places and dates of the survey

For an effective survey, it is important:

– to select the plots where pests or results of their activity (excrements, typical damage) may be found;

– to do the right choice of dates for recording certain pests or the results of their activity.

Each insect species is characterized by a certain cycle of seasonal development. In certain periods of life, certain stages of forest insects can be found in crowns, stems, or in soil. In addition, each insect prefers one or another forest plot in terms of host trees composition, age, the relative density of stocking, etc.

For example, *Tortrix viridana* hibernates in an egg on oak branches. Larvae usually appear simultaneously with leaves, develop in about 4–5 weeks, and then pupate. Soon the moths swarm, mate, lay eggs and die.

At the beginning of May, on the surface of the forest litter or any horizontal surface within the crown projection, the excrements of larvae are clearly visible, falling continuously. At the end of May, crown damage is clearly visible, with rolled leaves and larvae or pupae inside. Eggs can be found between current July and April of the next year, but for this, it is necessary to either climb into the crown or cut down a model tree.

Thus, the most convenient, accessible, and least time-consuming is the crown inspection in May. Oak leaves of early form bloom usually at the end of April - beginning of May, and in the second half of May, they reach their full size. At this time, it is necessary to reveal the fact of foliage damage. It should be borne in mind that simultaneously with *Tortrix viridana*, other larvae, beetles, and other insects feed. Therefore, it is necessary to identify their species composition and estimate their abundance to evaluate the threat to the forest.

However, if high defoliation of the crowns is detected shortly before pupation, then forest spraying with insecticides in the current year will not prevent crown damage. At the same time, the obtained data are the basis for a detailed survey and being ready to in time control the next year.

Another example is *Panolis flammea*, which hibernates as a pupa in the forest litter. The moths appear after thawing of the forest litter at the beginning of April, mate, and lay eggs on pine shoots. Larvae appear when the cover comes off the current year's shoots and current year needles become available for larvae feeding. They consume foliage until the 2nd or 3rd decade of June, and then descend into the forest litter and pupate. The pupae may be assessed from the end of current June to the beginning of April in the next year. These data can be used for forecasting the threat to the forest.

Other places of the survey are damaged shoots of the current year in late May - early June, as well as excrements on the forest litter during the same period.

8.3. Forest inspection

Inspection of forest stands is necessary for several goals:

– evaluation of the forest health condition and the causes of their deterioration or mortality;

– revealing the foci of forest pests and diseases and stands with impaired stability;

– assessment of quantitative parameters characterizing outbreaks of pests and diseases;

– mapping of foci boundaries and forecasting outbreaks development in the next year according to a predicted threat.

The *foci* of forest pests and diseases may be the subcompartments of forest stands, unclosed plantations, and nurseries, in which the tree damage in the current year exceeded 15% or the threat of such damage in the next year is expected.

Depending on the purpose, detailing, and accuracy of the work, forest pathology inspections are of the following types:

Extensive (reconnaissance) inspections cover a large area in short terms (visual inspection of forest health condition).

Extensive inspections may be aerial and ground.

Intensive (detailed) inspections reveal the causes of forest health deterioration (pests, diseases, air pollution, etc.), and assess some numerical characteristics of the forest health condition and pests' populations.

The required number of trees depends on the frequency of the trait. If less than 10% of the trees are damaged, at least 200 trees are assessed; if 10–20% of trees are damaged – 100 trees are assessed; 20–40% – 50 trees; more than 40% – 20 trees are enough.

A minimum of 2 model trees are taken per survey unit for assessing for pests in the crown, 2 sample plots for assessment of the pests in soil or litter, 10 trees for assessment for *Lymantria dispar* egg masses, 2 model trees for assessment of *Lymantria monacha* egg masses, 6 model trees for assessment for winter nests of *Euproctis chrysorrhoea*. In the survey area (forestry), 36 trees are taken for assessment for pests in the crown, 26 trees for assessment for eggs of *Tortrix viridana* and *Operophthera brumata*, 210 trees for assessment for nests of *Euproctis chrysorrhoea*, 350 trees for assessment for egg masses of *Lymantria dispar*, and 70 sample plots for pest assessment in litter or soil.

In the stands where the use of insecticides is planned, it is necessary to carry out additional assessments after winter, since the population number and the threat to the forest sometimes decrease due to the weather events and entomophages.

8.4. Principles of insect assessment

It is impossible to count the absolute number of individuals, therefore, we assess their number per accounting unit. Such a unit may be a tree, a branch of a certain length, with a certain surface area, foliage mass, shoots number, a plot of a given area within the crown projection, a pallet on the stem surface, etc.

Like a survey, populations should be assessed when insects are in stages

– which are easily noticed;

– which are detected for a relatively long time (during hibernation, feeding, and diapause).

It is most convenient to record foliage-browsing insects of pine forests when they are in the litter (cocoons of *Diprion pini*, pupae of the *Panolis flammea* or *Bupalus piniarius*, caterpillars of *Dendrolimus pini*).

It is very difficult to find the pupae of foliage-browsing insects (*Operophthera brumata*, *Phalera bucephala*, *Notodonta anceps, Calliteara pudibunda*) in the litter of oak forest because, unlike the sandy soil of pine stands, the soil in deciduous stands is rather heavy, permeated by the roots of trees, shrubs, and grasses. For an assessment of these species, special methods are used, in particular, accounting of *Operophthera brumata* in trap belts.

Usually, the timing of insect assessment depends on their phenology, but necessarily covers feeding and hibernation periods.

Assessment of foliage-browsing insects during the feeding period is convenient because it is possible to evaluate the crown damage.

Direct assessment of insect larvae in the crown is complicated by the need to climb into the crown and cut individual branches or whole trees. At the same time, a certain number of larvae is shaken off the branches and is not taken into account.

Of the indirect methods of insect assessment during their feeding in the canopy, the most common is the estimation of the excrements that fell on the sample boxes placed on the ground in the crown projection. The method makes it possible to assess the population density of insects in different parts of the forest almost simultaneously and is quite effective if one insect species dominates in the canopy, and larval development do not vary greatly within the tree and stand.

Another indirect method of insect assessment while feeding in the crown is the evaluation of defoliation level. However, this method also has a number of disadvantages. Crown damage of up to 5% cannot be quantified, and damage of more than 30% of pine needles and more than 50% of oak leaves is a reason for spraying the forest with insecticides. In addition, the same number of larvae corresponds to a different level of damage to the crowns depending on trees’ health condition, the seasonal temperature, the phase of the outbreak, etc.

CHAPTER 9. FORECAST FOR THE FOREST PROTECTION

9.1. Issues and types of forecast

Phenomena that do not repeat are impossible to predict. Any forecast is based on an analysis of the spatial and temporal dynamics of certain phenomena or processes in the past, and relationships with various factors and processes. Since it is impossible to take into account all factors and processes in nature, any forecasts are made with a certain probability.

That is, a forecast is a probabilistic judgment about trends and prospects for the process development in the future based on past and present information.

The forecast for forest protection considers the following main issues:

1 – what insects, fungi, or other pests can cause forest damage?

2 – where (in which regions, forest site conditions, under what age, composition, and relative density of stocking) such damage can be high?

3 – when (under which global or local conditions) the population of harmful organisms increases;

4 – how to evaluate the harmfulness of certain species and the expediency of protecting the forest, forest seeds, planting stock

or forest products;

5 – what are the optimal dates for the detection, and assessment of harmful organisms and forest protection?

These issues have different importance for the protection of different objects: fruits and seeds, planting stock, unclosed plantations, forests of different ages and targets, and forest products, as well as for different lead times of forecasts.

In terms of lead time, forecasts are divided into long-term (strategic), annual (tactical), and seasonal (operational) ones.

9.2. Long-term forecast

The aim of the long-term forecast is the compiling lists of pests (WHO?), zones, areas, and stands with a high probability of outbreaks, i.e. zoning (WHERE?) and the expected frequency of outbreaks or the year of the next outbreak (WHEN?).

Long-term forecasts give the possibility to justify the strategy of forest protection, changes in the structure of the Forest Protection Service, and improve the personnel training system.

Long-term forecasts can only be based on the analysis of large amounts of information regarding the distribution, and dynamics of pest populations and the factors influencing them. Long-term forecasts can be made only by research institutions using modern GIS technologies, modelling, etc.

WHO? The main list of pest species remains unchanged, but the role of individual species may change. So, in the late 40's – the early ‘50s in the territory of Ukraine, outbreaks of *Malacosoma neustria*, *Euproctis chrysorrhoea*, and *Phalera bucephala* were recorded, which became significantly rare in subsequent years.

Changes in the pest composition are largely associated with an increase in technogenic pollution, in which smaller species, species with a hidden lifestyle, and sucking mouthparts survive. An increase in temperature favours the spread of multivoltine species.

An increase in climate aridity increases the susceptibility of trees to any factors and improves the conditions for the adaptation of alien pests that have penetrated beyond their natural ranges with growing stock, packing containers, timber products, and "hitchhiking" on various vans and transport modes.

Every year hundreds of species of insects, fungi, and bacteria spread to new regions. A lot of them are extinct, others are left in a small number, and we don’t know about them, and some of them become pests, although in the native area they didn’t show a notable impact on the forest health.

Therefore, the researchers have to predict which species will settle in the forests of the country, and whether they will be able to form outbreaks and cause significant damage to the forest, planting stock, or forest products. As insects, fungi, and other species change their ranges everywhere, different countries are accumulating databases from which it is possible to learn about the routes already taken by these species and their behaviour in different regions, in particular the host plants, the seasonal development, the requirements for temperature and humidity during feeding and wintering, presence of natural enemies, etc.

WHERE? The basis for zoning the territory according to the frequency or severity of outbreaks of individual pest species is long-term data on the dynamics of their outbreaks' area in the forests of different regions and forestry enterprises. Such zones are not fixed and their boundaries must be adjusted to climate change and forest structure.

If the frequency, severity, and duration of outbreaks of a certain pest, according to long-term data, are the largest in some areas, then in the future with a high probability we can expect their greater distribution in these areas.

The frequency of outbreaks and the intervals between them are also determined from the data on the long-term outbreak dynamics. However, a relatively constant period between outbreaks is characteristic of foliage-browsing insects. Other groups of pests (for example xylophagous insects) are more dependent on the availability of vulnerable host plants.

At the level of geographical populations, the long-term forecast of the next outbreak is based on the history of outbreak years of previous decades, and at the level of ecological populations, on the population densities in individual foci.

It is known that the foci of most foliage-browsing insects are confined to the most lightened and warmed-up stands, including the edges, the borders with clear-cuts, burned areas, and unclosed forest plantations. Separate species and ecological groups of phytophagous insects are confined to certain types of forest site conditions, certain host species, age, and relative density of stocking.

Approaches have been developed for scoring forest subcompartments in terms of the risk of outbreaks formation of foliage-browsing insects, xylophagous insects, pine bark bug, etc. For each subcompartment such scoring can be processed and the area of high risk evaluated for forestry or for whole forest enterprise. Such an assessment should be corrected at least during subsequent forest inventory, and even more often in case of sharp changes in the forest fund, particularly after a fire or sanitary felling over a large area as a result of an outbreak of bark beetles.

WHEN? The long-term insect population dynamics depend on the weather conditions in the years of the outbreaks, and the terms, and rates of their seasonal development. Thus, the foci of insects that hibernate in the egg stage (*Tortrix viridana*, *Neodiprion sertifer*, *Lymantria dispar*) most often occur in years when larval feeding begins the earliest. Under such conditions, they feed on the youngest leaves, which contain a lot of nitrogen and few protective substances, quickly complete their development and avoid the entomophages.

Conditions for the earliest hatching and start of larval feeding are most often in years of solar activity decrease within the 11-year cycle. Such years are characterized by early spring, high air temperature, and low humidity. Such conditions are favorable for foliage-browsing insects that begin development in early spring. In addition, with low humidity, the resistance of trees to damage by insects decreases.

The formation of outbreaks of insects that hibernate in the caterpillar stage is facilitated by dry and hot weather conditions during the development of young larvae, i.e. the previous year. For example, the caterpillars of *Dendrolimus pini* and *Euproctis chrysorrhoea* continue their development in the spring and early summer, pupate, turn into butterflies and lay eggs, from which the caterpillars of the new generation hatch in July. Dry and hot weather in the second half of summer contributes to their rapid development and greater viability.

Likewise, if the weather is dry and hot during the feeding period of the younger caterpillars of insects that hibernate in the pupal stage (in May-June for *Panolis flammea*, in July-August – for *Bupalus piniaria*), then next year there is a high probability of growth in the populations of these pests.

9.3. Annual (tactical) forecast

The annual (tactical) forecast is aimed at correcting long-term forecasts, detecting trends in the dynamics of ecological populations, evaluating the threat of stand damage, and decision-making on the advisability of forest protection measures.

The annual forecast characterizes the distribution of individual pests expected in the next year, as well as population density in particular stands. At the same time, the distribution of individual insect species, and the intensity of their propagation and survival allows for determining the outbreak phase and the potential threat to the forest. Such a forecast, based on a forest survey, is necessary for substantiation, current planning, and organization of forest protection. The annual forecast is carried out by forest protection enterprises.

9.4. Seasonal (operative) forecast

Seasonal (operative) forecast gives the possibility to determine the dates of insect survey, assessment, and control, to correct the dates of planned measures considering weather conditions and insect survival in the current year using the relations between dates and rates of insect development with temperature as well as phenological indicators.

Determining the timing of pest control is based on the phenology of insects and host plants. The reaction of any poikilothermic organism to temperature is characterized by the threshold of development and the sum of temperatures, which vary depending on latitude, photoperiod, mean temperature during development, the physiological condition of insects, the phase of the outbreak, and certain parameters of the forest environment.

Failures in the use of sums of effective temperatures are also explained by the difficulty of taking into account the effective heat at the beginning of spring, or (for insects wintering in the soil) -

differences in the heating of the soil and air.

To determine the optimal dates for controlling foliage-browsing insects, it should be remembered that young larvae are most susceptible to insecticides.

Species that have one generation per year and overwinter in the egg, pupa, or eonymph stage have one feeding period, and species that have two or more generations have a correspondingly larger number of feeding periods.

Species that have one generation per year and overwinter in the larvae stage have two periods of feeding - in the spring after the end of winter and in the second half of summer when the larvae of the new generation hatch.

Foliage-browsing insects, which hibernate in the egg and larval stages, start feeding after the date of stable transition of the average daily air temperature over 10 °C. On average, this is the third decade of April, the phenological signal is the blooming of birch and early oak leaves.

The beginning of the swarming of *Panolis flammea* corresponds to the date of a stable transition in air temperature over 5 °C (thawing of the upper soil layer, pollination of hazel), the *Diprion pini* - over 10 °C.

The larvae of *Panolis flammea* hatch, if the cover comes out of the pine shoots - approximately in the first decade of May. After several days, the larvae of *Diprion pini* hatch. The date of the hatch of *Bupalus piniarius* larvae coincides with strawberry ripening. Caterpillars appear in July.

The latest dates for larvae feeding, which means the latest dates of forest spraying against *Tortrix viridana*, *Archips crataegana*, *Operophthera brumata*, *Neodiprion sertifer*, *Panolis flammea* are the second, or worse, the third decade of May.

The larvae of *Bupalus piniarius* and the larvae of the summer generation of *Diprion pini* complete their feeding after a stable transition in the air temperature below 15 °C, of the *Dendrolimus pini* - below 10 °C.

The use of insecticides to control these insects must be carried out in August, at the latest at the beginning of September. After a stable transition in the air temperature below 15 °C, it is possible to count the egg masses of *Neodiprion sertifer*, and after its transition below 5 °C to count the wingless females of *Operophthera brumata* in trapping belts on the stems, and a little later – its egg masses in the crowns.

9.5. Prediction of foliage damage by foliage-browsing insects

Usually, about 30 % of needles or 50 % of leaves loss is not dangerous for tree vitality. However, weakened trees have less foliage than healthy ones. Therefore, this foliage can be damaged by a lesser number of larvae.

The level of crown damage by the larvae of foliage-browsing insects is calculated based on the data on the critical and actual population density (larvae/tree).

Critical population density is the number of the 1st instar larvae which can consume 100% of foliage mass in the tree of a given diameter and height. Critical population density is evaluated by dividing foliage mass per tree into feeding norms of larvae of given species.

Foliage mass per tree is calculated in the "*Standards of evaluation of components of aboveground trees biomass of trees of the main forest-forming species of Ukraine"* (Lakyda et al., 2011) for oak and pine stands in the forest and forest-steppe zones of Ukraine.

Considering the fact that the foliage mass on a tree decreases as its health condition worsens, to evaluate the foliage mass for trees of the II (weakened), III (severely weakened), and IV (drying) health condition classes, we must multiply the foliage mass of healthy trees (I class of the health condition) by 0.8; 0.4 and 0.16, respectively.

To predict the level of crown damage by insects, it is necessary to assess the health condition of 100 trees and calculate the average value, in accordance with this, choose a table to assess the critical larvae number of a certain insect species. (*Norms of quantitative indicators of the impact of harmful insects on the condition of pine and oak trees in the stands of the plain part of Ukraine and the mountainous part Crimea / responsible compiler V.L. Meshkova Kh., 2014. 155 p.)*

9.6. Forecasting changes in the forest health condition after being weakened by various factors

The health condition of trees of I-IV classes may deteriorate or improve. The probability of a change in the tree's health condition depends on the cause of damage and environmental conditions. This parameter is estimated by the frequency of changes in the tree health condition from one class to another, assessed during research at sample plots.

The determined frequencies of changes in the class of the tree health condition are used also to forecast tree mortality. Thus, if the initial distribution of trees by health condition classes is known, to predict the mortality, it is necessary to multiply the initial proportion of trees of each health condition class by the probability of their death, and then sum these products.

Let's assume that in the year of the fire, the pine trees are distributed by classes of health conditions in the following way: I – 50%, II – 30%, III – 20%. The probability of mortality of trees of the first class of health condition three years after the fire is 0%, of the second class is 2.9%, and of the third class is 2.7+19.8 = 22.5%.

The expected proportion of trees that can die will be:

$$50 * 0 + 30*2.9/100 + 20*22.5/100 = 5.37\%.$$

9.7. Harmfulness of stem insects

Xylophagous insects can cause physiological damage to living trees and/or technical damage to living, dead, and felled trees. The health of living trees can deteriorate if the galleries of xylophages cut off the supply of water and nutrients from the roots to the crowns, as well as in the case of significant damage to foliage, shoots, or branches at maturation feeding and if pathogenic bacteria, fungi or other harmful organisms penetrate the tree. The wood quality of living, dead and felled trees can deteriorate as a result of gnawing the galleries and the spread of blue-stain and wood-destroying fungi. For a quantitative assessment of the harmfulness of xylophages, a scoring system was developed about 50 years ago (Mozolevskaya 1974), which takes into account the effect of these insects on the health of living trees and on the timber quality.

Evaluation of harm from stem pests includes:

i) General harmfulness = technical damage × physiological damage × correction coefficient (1 – for one-generation per year, 2 – for two generations per year, and 0,5 for development during two, and more years).

ii) Physiological damage = physiological activity (ability to colonize trees of different health condition) + ability to damage the trees during maturation feeding + ability to vector the pathogens.

iii) Technical damage = general wood destruction × colonized area × damaged wood value.

iv) By the general harmfulness score, all studied xylophagous insects are referred to four groups, namely, highly harmful (the general harmfulness is 80 and more points), moderately harmful (20–79 points), low harmful (10–19 points), and non-harmful (less than 10 points).

However, the harmfulness of the same species of stem insects depends on the region, year, tree health condition, and the timing of their damage by other factors.

9.8. Harmfulness of insects in unclosed plantations

The scales are developed to assess the damage severity to Scots pine transplants in unclosed plantations (up to 5–7 years old), taking into account the damaged organs of a tree by direct and indirect symptoms. Indirect symptoms are especially important in case of root damage that cannot be examined in living plants. When assessing the direct symptoms of plant damage, the intensity of damage to needles, buds and shoots, stems and branches, root collars, and roots is separately assessed. Some types of damage, for example, in the underground part of plants, can be detected by indirect symptoms. A rating scale was developed for assessing the intensity of damage to unclosed pine plantations using indirect symptoms. Thus, the average level of plant damage corresponds to defoliation of 31–60%, discoloration of up to 50% of needles with needles 2–4 cm long, and health condition class 3.0–3.9 points. A high level of insect damage corresponds to defoliation over 60%, discoloration over 50%, the length of the needles less than 2 cm, and the class of the health condition of trees over 4 points.

Damage to individual pine organs in forest plantations has a different effect on plant viability (mortality rate), growth rate, and stem quality. In accordance with this, on the basis of an expert assessment, weight factors were evaluated for the assessment of the impact of individual pests on the mentioned parameters of the health condition of plantations. Thus, the effect of damage to needles, buds, and shoots on plant mortality is assessed by point 1, and on growth – by point 2, the effect of buds and shoots damage on stem quality – by point 3.

To calculate the effect of insect damage on the growth and health condition of unclosed pine plantations it was proposed to examine at least 50 plants, assessing by points the intensity of damage to needles, buds and shoots, stem and branches, root collar and roots. In this case, root damage of dead plants is determined by digging them up, and of living ones - by indirect signs (defoliation, the size of needles, etc.). Using the weight factors, the effects of pest damage on growth, mortality, stem quality, and the overall effect on the plant are calculated.

9.9. Super-long-term forecasting

In recent decades, the importance of long-term (super-long-term) forecasting has increased. It takes into account climate change and the associated change in the structure of the forest fund (in particular, changes in the tree species composition).

Climate change manifests itself mainly in an increase in temperature and a decrease in precipitation. An increase in temperature in the northern regions may contribute to an increase in forest productivity.

With a decrease in precipitation, the intensity of transpiration increases, which is unfavourable for trees. They can adapt to new conditions by reducing the foliage mass, which will increase their vulnerability to damage by phyllophagous insects. Fewer larvae will be able to consume 100% of foliage than currently calculated.

A decrease in precipitation will lead to a decrease in the groundwater level. This will be unfavourable for trees, especially those with a shallow root system, such as spruce. At the risk of lack of soil moisture, more sparse stands will be more stable. However, such stands are the most attractive for phytophagous insects.

Models have been developed that predict changes in the ranges of the main forest-forming tree species. So, according to them, our main forest-forming species may extinct in the next 100 years. If tree composition changes, then the composition of harmful organisms that are of economic importance will also change.

What changes will occur in the outbreaks of foliage-browsing insects under climate change?

Since insects are poikilothermic organisms, i.e. sensitive to environmental temperature, warming will directly affect the duration of insect development, survival, the number of generations, and diapause (winter, sometimes summer pause in development under unfavorable conditions).

If the temperature does not exceed the limit optimal for insect survival, their development will accelerate. This will enable the appearance of additional generations of some species, which currently have mostly one generation. An increase in winter temperatures, on the one hand, will contribute to the survival of insects in winter, and on the other hand, it will lead to a decrease in the height of the snow cover and reduce the protection of insect wintering places.

Indirect impacts of climate change on insects may occur through host plants, natural enemies, and insect pathogens.

The impact through the host plant will be manifested through plant health condition and phenology, in particular, through violation of synchronicity in the spring development of insect larvae and tree leaves. If the new conditions are unfavorable for trees, weakened trees will become more attractive to insects. On the other hand, if tree species that are vulnerable to climate change will extinct, then for a certain time the insects will either adapt to feeding on other host trees or will be replaced by other insect species.

The distribution and number of natural enemies of foliage-browsing insects, as well as their preys, depend on the direct influence of climatic factors. In particular, these factors affect survival during wintering, seasonal development, and the number of generations. There is an assumption that the sensitivity of entomophages to climate change is greater than that of phytophages. Entomophages, capable of feeding on many species of phytophagous insects, adapt more easily than specialized parasitoids or predators. As in the case of the link between a tree and phytophagous insect, in the link between phytophagous and entomophagous insect, the synchronicity of development plays an important role, especially in spring. For example, a parasitoid can infest prey larvae of a certain species only up to the third instar. If at the time of the parasitoid leaving from the wintering places, the prey larva has the fourth or the fifth instar, the parasitoid will not be able to lay eggs in this host, and if it does not find another host, it is doomed not to leave offspring at all.

High temperatures can directly affect predation levels, as predator and prey will increase activity. If a predator hunts actively, its success will depend on who is more agile - the predator or the phytophagous insect. If a predator is waiting for a victim in an ambush, its success will depend on the prey’s activity.

Pathogens of insects (fungi, bacteria, and viruses) usually actively affect foliage-browsing insects at the high population level. Changes in the environmental temperature will affect the rates of insect development, diseases, and the protective reactions of the insect's organism. The insect and the pathogen may have different optimal temperatures, and increasing the temperature will increase the resistance of the insect to infection. In the successful development of fungal pathogens, humidity plays the greatest role, and it will decrease at high temperatures. On the other hand, these pathogens can actively destroy insects that winter in the forest litter at a favorable combination of temperature and humidity there. Viruses affecting foliage-browsing insects often experience unfavorable conditions for themselves in the form of protein inclusions - granules and polyhedra, which are saved in the forest environment for decades. At the same time, these formations are very vulnerable to UV radiation. Therefore, on the one hand, an increase in temperature will decrease the incubation period of insect diseases after infection, and on the other hand, a significant decrease in the stock of viral material in the forest due to inactivation by sunlight is possible.

CHAPTER 10. IMPLEMENTATION OF IPM TACTICS

10.1. Preventive and active measures

Forest protection measures are subdivided into preventive and active ones. *Preventive measures* are aimed at increasing forest stability and preventing the appearance of foci of harmful organisms.

Active measures are aimed at reducing the populations of harmful organisms and the localization of their outbreaks.

Preventive measures include mainly sylvicultural methods that are performed throughout the entire cycle of forest cultivation and forest use with the aim of increasing the resistance of forests to pests, diseases, and other adverse environmental factors, which ensures the preservation of the forest, eliminates or reduces the possibility of its damage and increases stability.

Sylvicultural methods include:

– the use of healthy seed and planting stock for afforestation, its proper storage, and transportation;

– compliance with the agrotechnical rules in nurseries and plantations, which contribute to obtaining healthy seedlings and transplants of the first grade;

– creation and forming the mixed and, if possible, uneven-aged stands;

– justified selection of forest tree species composition, considering climatic and forest site conditions, resistance to damage, and the possibility of the transition of harmful organisms from one tree species to another;

– selection of resistant forms of trees;

– timely and systematic care;

– justified selection of the main felling parameters and the terms of their implementation;

– control the forest health condition, and timely application of sanitary measures.

10.2. Biological method of forest protection

The biological method of forest protection is the regulation of pest populations by beneficial ones. It assumes that natural enemies (parasitoids, predators, and pathogens) can keep the population of their host (prey) at a lower level than in their absence.

Biological control of forest plant material becomes imperative in regard to EU regulations on Integrated Pest Management (IPM) requiring a search for alternative plant protection methods that are safe for humans, animals, and the environment.

There are three primary methods of using biological control:

– conservation of existing natural enemies,

– introducing new natural enemies and establishing a permanent population (called "classical biological control")

– mass rearing and periodic release, either on a seasonal basis or inundative one.

Entomophagous species may be insects (parasitoids and predators), and other invertebrate and vertebrate animals that can eat phytophagous insects.

Larvae and adults of predators kill more than one individual of phytophagous insects for their life.

Larvae of parasitoids develop mainly at the expense of one host.

Predators are known in 16 orders and 167 families of insects.

Xylophilic predator insects (mainly beetles) live in wood. They can be obligate or facultative predators.

Obligate predators are the members of Cleridae family. Thus, species of the genus *Thanasimus* are related to bark beetles on conifers.

Facultative predators can also feed by organic residues in xylobionts' galleries, mushrooms, rotten bark or wood, and remains of dead insects, but animal food is definitely needed for their development.

10.3. Diseases of forest insects

Diseases of forest insects. All organisms that cause insect diseases are called entomopathogens. They can be viruses, fungi, bacteria, protozoa, nematodes, etc.

Depending on the pathogen features, the disease can develop acutely or chronically. The acute development of the disease occurs at a high density of the insect population.

The widespread occurrence of infectious disease among one or more insect species over a large area is called *epizooty*. Insect epizooty is an analog of the human epidemy and plant epiphytoty.

Infectious diseases mainly affect insect larvae, occasionally eggs, pupae, and adults (mushrooms). Insect diseases are characterized by specific symptoms that most often appear before or after death.

Among the viral diseases of insects, baculoviruses (Baculoviridae) or rod-shaped viruses are the most common, in which the virions are rod-shaped (Greek: "Baculum" - rods).

According to the morphology of the inclusions, such diseases are called polyhedroses or granuloses. Such diseases are known only among insects, mainly Lepidoptera and Hymenoptera.

Among bacterial pathogens, *Bacillus thuringiensis* is the most common and is the base of several bacterial preparations.

Among fungal pathogens, *Entomophthora, Muscardina* and *Beauveria* are the most known.

10.4. Biopreparations based on microorganisms

Microorganisms are isolated from dead insects and the most active strains are selected. Some biological preparations contain not the microorganisms themselves that are active, but their metabolites. Bacteria and fungi are reproduced on a special medium, and viruses - in living insects or in the culture of their tissues.

Most bacterial preparations are based on the bacterium *Bacillus thuringiensis*, which forms crystals. These crystals are toxic to insects. The examples of bacterial preparations are lepidocide, bitoxybacillin, bicol, dendrobacillin, insectin, homelin, and entobacterin.

Viral preparations are specific. Virin NSh is intended for protection against *Lymantria dispar*. The working substance is a suspension of polyhedra in 30% glycerol. It is used for processing egg masses. Caterpillars become infected after hatching and spread the infection. In the focus of this pest, 10-20% of egg masses are treated at the rate 0.0002 - 0.002 l per egg mass. In the case of aerial spraying of the forest against caterpillars of 2-3 instars, the dosage is 0.025 l/ha.

Virin-RSP is used against *Neodiprion sertifer* in the rate 0.01-0.004 l/ha during aerial spraying of pine stands, Virin-ZSP – against *Diprion pini*.

Fungal preparations penetrate the insect not only at feeding but also through the cuticle. They affect insects of different species at different stages that do not feed. Boverin is used against soil pests. The rate is 1-2 kg/ha. Verticillin is used against sucking pests (aphids, thrips, whiteflies) in green houses.

10.5. Chemical forest protection

Chemical forest protection is based on the use of organic and inorganic substances toxic to harmful organisms. Chemical substances are applied directly to these organisms, to the surface of various plant organs, or are introduced into the soil and wood.

The advantages of the method are the possibility of mechanization and fast action.

The disadvantage is a negative impact on beneficial fauna, soil microflora, toxicity for humans and animals.

Chemical substances used in plant protection are called pesticides (lat. *pestis* – infection, destruction, *cide* – to kill).

Pesticides are classified by chemical composition, objects of application, nature of action, and methods of penetration into the organism.

According to the objects of application, pesticides are divided into: insecticides (*insectum* - insect) - against insects; acaricides (*acarus* - tick) - against ticks; insectoacaricides - simultaneously against insects and mites; ovicides (*ovum* – egg) – to destroy eggs; larvicides (*larva*) – against larvae; molluscicides – against mollusks; nematocides (*nematodes* - roundworms, phytohelminths) - against nematodes; rodenticides (zoocides) – against rodents; fungicides (*fungus* - mushroom) - against fungal diseases; bactericides (*bacteria*) - against bacteria; antiseptics (*ant* – against, *septicos* – causing rot) – against wood rot; herbicides (*herbum*, *herbi* - grass) - against unwanted herbaceous (weeds, poisonous plants) vegetation; arboricides - against an unwanted tree and shrub vegetation; algaecides - to destroy algae; aphicids - against aphids; vermicides - against worms; virocides - against viruses; chemosterilants - for sexual sterilization of insects.

Many of these substances affect various groups of harmful organisms.

According to the chemical composition pesticides include inorganic compounds (compounds of mercury, copper, sulfur, fluorine, barium); organic compounds (organochlorine, organophosphorus compounds, synthetic pyrethroids, derivatives of carbamic, thio- and dithiocarbamic acids, nitrophenols), preparations of plant, bacterial and fungal origin (pyrethrins, antibiotics).

According to the nature of action, insecticides are divided into groups of intestinal, contact, systemic action, and fumigants. Intestinal insecticides should enter the digestive system of insects, contact insecticides cause death during penetration through the skin; systemic insecticides enter plants, move in their tissues, and cause the death of pests that feed on plant juices and tissues; fumigants penetrate through the respiratory tract in the form of gas or vapor. Many insecticides have several types of action.

10.6. Pheromones

Pheromones (Greek: *pherien* - to carry and *horman* - to excite) are chemical substances with the help of which insects transmit information to individuals of their species (chemocommunication). Pheromones belong to attractors - attractants (lat. *attractio* - attraction), the pairs of which cause the appropriate reaction of insects. By origin, attractants may be natural or synthetic. Natural ones are obtained from fodder plants and insects, the second ones are synthesized.

Pheromones are produced in the body of insects and are secreted by exocrine glands. Some individuals emit them, and others perceive them and react with behavior - they gather, find a partner, food, etc.

Sex pheromones are the most widely used in forest protection:

– for attraction to estimate the population level and terms of appearance;

- for destruction;

- for saturation of the environment and disorientation of males (creating a "male vacuum").

10.7. Systems of forest protection measures

The system of forest protection measures is a combination of methods, techniques, and means used to protect forest stands and other objects from pests and diseases.

These objects include mature forests, seed plantations, seed and wood storage places, nurseries, unclosed forest plantations, cultivated areas, clear-cuts, etc.

The protection of various objects of forest management from pests requires the implementation of general and specific methods, means, and technologies, which make up systems of forest protection measures in relation to individual species and complexes of harmful organisms. The creation of conditions unfavorable for pests and pathogens and active methods of their direct destruction or suppression is included.

Systems of forest protection measures include almost all methods of forest protection: organization of forest pathological monitoring and survey of the appearance and spread of harmful organisms; measures to increase the forest stability; active methods of plant protection, ecological and economic evaluation of the results of the application of measures.

The task of forest protection is not to completely exterminate the pest population, but to reduce it to a certain limit level. Such a trend meets modern requirements for any human influence on nature.

10.8. System of protection of generative organs of woody plants (cones, acorns, fruits and seeds)

The system of protection of fruits and seeds of woody plants includes the organization and implementation of the survey, the implementation of the rules of forest damage prevention in forest seed enterprises, the correct harvesting and storage of fruits and seeds, their inspection, and active methods of protection. Fruits and seeds are protected during ripening in stands, storage, and sowing. It is most difficult to organize the protection of fruits and seeds in trees when pests having a hidden lifestyle, are inside the cones, fruits, and seeds.

The purpose of the survey is to identify the species composition of pests and pathogens, and their development, and to estimate losses from them.

A survey is carried out by periodic collection and analysis of fruits (acorns) or cones. They are analyzed at least 2 times a year according to the terms of their development, as well as the biology of the main pests. Thus, spruce cones are harvested for the first time 10-12 days after the scales are closed and the cones are turned upside down, and the second time - after the end of the growing season in October - November.

Within the plot, 3-5 fruit-bearing trees are chosen for survey, and several dozen cones, acorns, or other fruits are selected from them by random sampling. The cones or fruits are examined, then dissected, all pests are taken into account and the population density, the prevalence of each species, and the proportion of damaged cones are estimated. This gives the basis for a conclusion about the species composition of insects, their population density, and their harmfulness. Based on these data, it is possible to evaluate the possible crop losses.

Seeds should be collected mainly in so-called *seed stands*, *clonal seed orchards*, and *seedling seed orchards*.

Such stands should be resistant to various abiotic and biotic factors and have high rates of growth and wood quality. The stands are constantly formed, leaving trees of better growth, with a developed crown, and a straight stem.

The worst trees are gradually removed. In order to increase the seed yield, the upper canopy of the tree stand is systematically thinned. Since pests of fruits and seeds are mainly photophilous, it is necessary to thin the canopy evenly, and gradually, leaving up to 1-2 m between the crowns of neighboring trees. First of all, trees inhabited by stem pests, diseased, dry ones are removed. At the plots, an understory of shrubs improves the soil. Perennial grasses which bloom throughout the summer are sown on the edges of the forests. Such measures create favorable conditions for entomophagous insects and insectivorous birds. At such plots, it is necessary to ensure thorough care of the soil, and protection against harmful organisms.

It is important to choose the optimal seed harvesting dates and methods, taking into account the biological characteristics of tree species in local conditions.

Seeds (except acorns and other fruits with a high moisture content) should be stored in warehouses and special seed storage facilities in a state that is close to air-dry. Storage rooms are periodically ventilated, cleaned, and disinfected. They maintain optimal air temperature, humidity, and aeration.

The timing of the application of insecticides is determined in accordance with the phenology of the host tree and the main pests in a given region.

All batches of tree and shrub seeds must undergo a phytopathological examination at the *Forest Seed Center* or Regional department of Forest Seed Center before sowing. According to the results, the quality class and the need for fungicide treatment are determined.

10.9. Plant protection system in nurseries and young plantations

Preventive measures. The nursery must not be established on heavy and wet, clay and loamy soils, on windy and south-facing slopes and low places. Flat wind-protected places must be chosen at a distance of at least 100 m from the forest walls, preferably 250-300 m, to avoid the spread of pathogens and pests. Deciduous trees near the nursery attract cockchafers, so they must be cut down or sprayed.

In the case of even 1 cockchafer larva per 1 square meter, insecticides must be applied.

Areas for growing seedlings and saplings should be protected from weeds and harmful soil insects. Fertilizers, plant growth stimulants, etc. must be used.

Trap ditches against insects and rodents must be dug, and hedges of thorny bushes that are not damaged by cattle but inhabited by insectivorous birds must be planted around the perimeter of the nursery.

The seeds must be sown as early as possible. It is necessary to avoid dense crops and protect from birds (using scarecrows). It is necessary to regulate the intensity of watering, shade the plants in time, and loosen the crops regularly.

Planting stock must be sorted after digging, and diseased plants removed.

The soil for forest plantations must be tilled. This measure destroys insect pupae. Larvae dry up, are plowed deep, are injured by tools, and rodent burrows are destroyed.

If the areas are inhabited by cockchafers, deep (22-26 cm) tillage and a two-year pause before planting are mandatory. Bending tree roots during planting must be avoided. Mixed plantations and bushes around them are preferable.

Active protection. Physical & mechanical methods of plant protection include the collection and destruction of egg masses, larvae, beetles, nests, galls, and catching at the light.

Special methods of plant protection against large pine weevil and other pests are used according to recommendations.

10.10. Forest protection system against foliage browsing insects

Preventive methods include increasing forest stability and pest resistance, and attraction of entomophages. Creation of mixed evenly closed stands with complex tree species composition and structure. Survey and forecasting approaches are described in previous chapters.

10.11. Protect from vascular and necrotic-cancerous diseases

A survey should be carried out in July-August when external symptoms are visible: characteristic drying of individual shoots and branches in the crown or the entire crown, sporulation, etc.

Sylvicultural measures:

– timely and systematic care of unclosed forest plantations with the removal of diseased, inhabited, and weakened trees;

– carrying out thinning and sanitary felling in the autumn-winter period;

- maintenance of optimal relative density of stocking;

- forming tree stand composition in accordance with climatic and forest site conditions, vulnerability to diseases, and the possibility of disease transfer from another tree species;

– the creation of mixed and uneven-aged plantations;

– reconstruction of stands by changing tree species composition and soil improvement;

- removal of trees inhabited by stem pests, which contribute to the penetration of pathogens, are their vectors and accelerate tree drying in disease foci.

CHAPTER 11
BENEFICIAL INSECTS IN THE FOREST

There are millions of insect species in our world. However, less than one percent of these actually feed on plants in a harmful way. Many of the insects and spiders in forests do not harm a lot. Only a few of inhabiting insect species are pests. There are many more beneficial insect species than harmful ones. An ecologically healthy forest has diverse fauna. Each living organism plays a unique and usually beneficial role.

Beneficial insects are any species of insects that perform services like pest control and pollination. In addition, insects help to spread some plants. Ants are responsible for the germination of at least 150 plant species. Insects process the organic matter, then they deliver it into the soil as broken-down nutrients, which are much easier for plants to use during growth. Once a plant has died, insects start recycling the plant's nutrients back into the soil.

By eating all the leaves, and wood, insects are a link in the food chain. Bark beetles carry out the important task of forest health monitoring. These beetles recognize weak or sick trees, colonize them and helping ecosystem. Dead trees decompose and by using insects return their nutrients to the soil.

11.1. Kinds of beneficial insects

Beneficial insects are divided into three main groups:

1. Pollinators. Many insects including bees, butterflies, moths and different beetles pollinate flowers. Pollinators are major players in forest ecosystems. Insects pollinate about 80% of all trees.
2. Predators. These insects eliminate phytophagous insects by eating them. Ladybugs, praying mantises, and green lacewing larvae are predators.
3. Parasitoids. Parasitoids prey upon other insects, but unlike the predators, in a slightly different way. They lay their eggs on or in the host insect. When the eggs hatch, the larvae feed in the host insects. Parasitic wasps are the main representatives of this group.

11.2. Common beneficial insect species

Aphid midges (*Aphidoletes aphidimyza*) is a midge whose larvae feed on over 70 aphid species. They are active at night and hide beneath the leaves during the day.

Assassin bugs (family *Reduviidae*) use their sharp mouthparts to hunt down many different species of insect pests.

Damsel bug (family *Nabidae*). They are soft-bodied, winged terrestrial predators. They are benefit species because of their predation on many pest species.


Fig. 11.1. Aphid midge [21]


Fig.11.2. An adult assassin bug [22]

Hoverflies (family *Syrphidae*). The larvae of hoverflies are predators, devouring aphids, caterpillars, beetles, and thrips. They suck the juice from their preys.

Green lacewings (family *Chrysopidae*). The larvae of green lacewings prey upon soft-bodies pests, including caterpillars and aphids.

Ground beetles (family *Carabidae*) is a large group of predatory beetles. Both adults and larvae eat a wide range of pests, including nematodes, weevils, caterpillars, thrips, slugs, etc.

Ladybugs (family *Coccinellidae*) are ferocious predators. The larvae of ladybugs feed on aphids. One ladybug larva can eat up to 40 aphids per hour.

Minute pirate bugs (family *Anthocoridae*). Adults feed on smaller insects, larvae and eggs of spider mites, thrips, jumping plant lice, and white flies. Some species are reared commercially and sold for biological control.

Wasps the *Braconidae* family. They lay their eggs on the backs of caterpillars. Their larvae develop inside the host. White cocoons are formed on caterpillar’s back.

Trichogramma wasps lay their eggs inside the eggs of over 200 different insect pests. *Trichogramma* wasps are an active parasitoid of gypsy moth caterpillars, grasshoppers, some beetles, bugs, etc.

Fig. 11.3. Damsel bug [23]

Fig. 11.4. Hoverfly [23]

Fig. 11.7. Larva of ladybug [23

Fig. 11.8. Mature nymph of minute pirate bug [23]

Fig. 11.9. Eggs of Braconid wasp [24]

Praying mantises (order *Mantodea*). These predators hunt many insect pests: grasshoppers, beetles, moths, and flies. Praying mantises eat also other beneficial insects, such as bees, and even each other.

Robber flies (family *Asilidae*) have extra-long legs and hunt a number of common pests.

Most animals digest food in the intestines (stomach) using gastric juices. The spider digests its prey (insect) by injecting a poisonous secret into it. The tissues of the insect become soft, and the spider sucks them up.

Fig. 11.10. Trichogramma wasp [25]

Fig. 11.11. An adult praying mantis [23]


Fig.11.12. An adult robber fly [23]

Table 11. 1. Preferences of beneficial insects

Insects	Preys on	Attracted by
Aphid midges	Aphids	*Anethum graveolens* L. Plants with plenty of nectar and pollen
Braconid wasps	Aphids Caterpillars	*Achillea millefolium* L. *Melissa officinalis* L. *Petroselinum crispum* (Mill.) Fuss.
Damsel bug	Aphids Cabbage worms Caterpillars Mites	*Carum carvi* L. *Foeniculum vulgare* Mill. *Mentha spicata* L. *Solidago* L.
Green lacewings	Aphids Leafhoppers Mealybugs Whiteflies	*Anethum graveolens* L. *Angelica* L. *Coriandrum sativum* L. *Medicago sativa* L.
Ground beetles	Caterpillars Cutworms Slugs	*Amaranthus* L. *Trifolium pratense* L. *Oenothera biennis* L. *Mentha spicata* L.
Ladybugs	Aphids Whiteflies	*Achillea filipendulina* Lam. *Anethum graveolens* L. *Aurinia saxatilis* (L.) Desv. *Taraxacum officinale* F.H.Wigg.
Minute pirate bugs	Aphids Caterpillars Spider mites Thrips	*Carum carvi* L. *Cota tinctoria* (L.) J.Gay *Foeniculum vulgare* Mill. *Mentha spicata* L.

11.3. Rules of introducing beneficial insects

There are some benefits of using beneficial insects. We do not need to use chemical pesticides. The non-toxic approach allows growing plants organically.

Chemical pesticides are just as deadly to the beneficial and harmful insectsBeneficial insects will stay if an environment is favourable for them.

The beneficial insects help save costs because they are free.

A number of insects start to show resistance to chemical pesticides. Between 500 and 1,000 insect species have developed resistance to pesticides since 1945.

With the help of flowering plants, it is possible to attract beneficial insects.

Plants in the families *Apiaceae* and *Asteraceae* are mostly attractive for beneficial insects. List of other plants that attract beneficial insects consist of *Achillea millefolium* L., *Alyssum* spp., *Anethum graveolens* L., *Asclepias* spp., *Borago* spp., *Calendula officinalis* L., *Coriandrum sativum* L., *Cosmos* spp., *Echinacea* spp., *Foeniculum vulgare* Mill., *Helianthus annuus* L., *Hyssopus officinalis* L., *Lupinus* spp., *Medicago sativa* L., *Nasturtium* spp., *Petroselinum* spp., *Phacelia* spp., *Rosa* spp., *Rudbeckia* spp., *Taraxacum* spp., *Tagetes* spp., *Zinnia* spp.

CHAPTER 12
ATTRACTING BIRDS AND BATS TO CONTROL INSECTS

Birds and bats may suppress arthropod outbreaks. Bats and birds are major agents of pest reduction. Some bird and bat species can be useful allies in running an IPM program. They are efficient predators of insects. Attracting of birds and bats is one of the ways of forest protection.

12. 1. Controlling pests with birds

Bird predation may play a critical role in reducing and maintaining low insect populations . Birds are the agents of natural insect control because they have been feeding on insects for millions of years. A swallow can devour 1,000 leaf hoppers in half day. A pair of hungry yellowthroats eat up thousands of plant lices. An oriole can paunch up 17 hairy caterpillars per minute. A cuckoo polish off 217 webworms for one eat and a wren may feed 500 insects to its progeny during the day.

Increased numbers of birds can lead to the complete collapse of insect outbreak. If birds were excluded from hunting in forests, the number of insects increases by 65 %. It is necessary to attract natural predators of insects by providing nesting and roosting habitats, and additional food sources for birds in forests. It is possible to use logging residues to preserve insects for birds. It was found that the abundance of young insect generation depends on seasons, the methods of felling, forest location and forest site conditions. The most dangerous species inhabit logging residues with a diameter of at least 5–6 cm. Less dangerous small species of bark beetles inhabit thinner logging residues. Therefore, small logging residues in dry conditions may be left on loggers, but large ones (more than 5–6 cm in diameter) should be immediately taken out.

The avifauna of Ukraine includes over 400 species. The most common bird species are presented below.

Blackbirds (*Turdus merula* L.). The adult females have mainly dark brown plumage. The adult male of the common blackbird has a yellow eye-ring and bill. It has a rich, melodious song. This species builds a cup-shaped nest, bound together with mud. It is omnivorous, it eats different insects, earthworms, fruits and berries.

Bullfinches (*Pyrrhula pyrrhula* L.) is a small bird in the finch family *Fringillidae*. It builds its nest in a bush or tree. It lays four to seven eggs. This species produces 2-3 broods per season. The food contains mainly buds and seeds of fruit trees. The song of bullfinch contains fluted whistles. This species does not form large flocks and is usually seen as a pair or a family group.

Chaffinches (*Fringilla coelebs* L.*)*. It is a widespread bird. The female is subdued in colouring. The male is brightly coloured with a blue-grey cap and red underparts. Both sexes have two white wing bars and white sides to the tail.

Chaffinches form flocks in open countryside and forage for seeds on the ground and caterpillars. Birds breeding in the colder northern areas of their range winter further south while those breeding in warmer regions are sedentary.

The female builds a nest with a deep cup in the fork of a tree. The clutch is typically 4–5 eggs, which hatch in about 13 days. The male bird has a strong voice.

Chickadees (*Parus major* L.). The bird belongs to the family *Paridae*. It is a widespread species. Most chickadees do not migrate except in extremely harsh winters.

The bird has a black head and neck, white cheeks, olive upperparts, and yellow underparts. It is insectivorous in summer but consumes a wider range of food in the winter months. It usually nests in a tree hole. The female lays about 12 eggs.

Cockoos (*Cuculus canorus* L.) This species is a widespread summer migrant to Europe and Asia, and winters in Africa. It has a greyish, slender body and a long tail. The legs are short. It lays eggs in the nests of other bird species. The common cuckoo's diet consists of insects and hairy caterpillars.

Doves, pigeons (*Columba livia* Gmelin) are members of the bird family *Columbidae*. The domestic pigeon evolved from this species. It is grey with two black bars on each wing. Few differences are seen between males and females. The species is generally monogamous. Habitats include various open and semi-open environments.

It breeds at any time of the year, but peak times are spring and summer. Eggs laying takes place up to six times per year. Birds are gregarious, living in flocks of 50 to 500 individuals. The nest is a platform of straw and sticks.

Fieldfares (*Turdus pilaris* L.). It is a member of the thrush family *Turdidae*. It breeds in forests and scrubs. It is omnivorous, and eats a wide range of insects and earthworms in the summer, and berries, fruits, and seeds in winter.

The fieldfare has a grey crown, a brown back, dark wings and tail, and white underwings. The sexes are similar in appearance but the females are slightly more brown. The male has a simple chattering song. Fieldfares nest in small colonies. The nest is built in a tree where 5–6 eggs are laid.

In summer, the birds are frequent in mixed forests. In winter, groups of fieldfares are found in open country, agricultural land, etc.

Goldfinches (*Carduelis carduelis* L.) are small birds. The male has a red face and a black-and-white head. The black wings have a broad yellow bar. The tail is black and is forked. The female has a smaller red area on its face. Males and females are very similar. The song is a twittering. It is found in open, partially forested space.

The nest is built entirely by the female. It is constructed of mosses, and lichens and lined with plant down. The nest is compact, generally located several metres above the ground. The clutch is 4–6 eggs. The parents typically raise 2–3 broods each year.

The preferred food is small seeds, but insects are also taken when feeding young.

Jays (*Garrulus glandarius* L.). It has brown plumage with a black stripe on each side of a throat, a bright blue wing and a black tail. The sexs look different from each other.

The most characteristic call of this bird is a harsh, rasping screech. The jay is well known for its mimicry. It can imitate the calls of prey birds.

Jay inhabits mixed forests, particularly with oaks. Birds build the nests in a fork or on a branch of a tree. The nest has made of twigs roots, grass, leaves, and moss. The clutch is 3–6 eggs. Only a single brood is raised each year.

Jay eats invertebrates, pest insects, acorns, beech and other seeds, blackberries, rowanberries, and small rodents. It she destroys the nests of other birds.

Nuthatches (*Sitta europaea* L.). It is a short-tailed bird with blue-grey upper parts, a black eye stripe and a long bill. The female is similar in appearance to the male, but it has slightly paler upper parts. The preferred habitat is mature forest with large, old trees. Nuthatches are monogamous. The nest is in a tree cavity, an old woodpecker hole. The clutch is usually 6–9 eggs. Normally only one brood is reared each year.

The nuthatch calls frequently, usually with a loud, sharp nois normally repeated twice. Most populations are sedentary.

The nuthatch eats mainly insects. In autumn and winter, the diet is added nuts and seeds. Individual seeds are hidden in cracks of the bark.

Orioles (*Oriolus oriolus* L.). It is a summer migrant in Europe, that spends the winter season in Africa. The male has black and yellow plumage, the female is a drabber green bird. Oriole inhabits a range of places: open broadleaf and riverine, mixed or coniferous forests. The nest is placed in a tree fork. The nest is deep cup-shaped. The clutch is usually 3-5 eggs.

It feeds on insects and fruits.

Quail (*Coturnix coturnix* L.). It is a small ground-nesting bird. The female forms a shallow scrape in the ground. It lays 8–13 eggs. It has a characteristic call of three repeated chirps. The female is generally slightly heavier than the male. The female is streaked brown with a white eye stripe, the male has a white chin.

This is a terrestrial species, which feeds on insects, and seeds on the ground.

Robin (*Erithacus rubecula* L.), is a small insectivorous bird. The female and male are similar in colouration. The bird has an orange breast and face. It is sedentary. It has two or three clutches of five or six eggs. It produces a fluting warbling song.

Siskin (*Spinus spinus* L.) is a small bird in the family *Fringillidae*. It is found in coniferous and mixed forests. The upper parts of the body are greyish green and the underparts are grey streaked. Its tail is black with yellow sides; its wings are black with a yellow bar. The female has a greyish-green head without a cap. The male has a yellow face and breast, with a black cap.

The song of this bird is a mix of twitters and trills.

Sparrows (*Passer domesticus* L.) is a bird of the family *Passeridae*, is found in most parts of the world. The Female is pale brown and grey. The male has brighter black, brown, and white, markings. It feeds on seeds, and insects. The sexes exhibit strong dimorphism. It is found in widely varied habitats. Nests are built in the crevices of houses, and tree hollows.

Most songs of these birds are variations on its short and incessant chirping call.

Starling (*Sturnus vulgaris* L). It has black plumage with a metallic sheen, the bill is black in winter and yellow in summer, and the legs are pink. It builds a nest in a cavity in which lays 4-5 eggs. It is omnivorous, eating a wide range of invertebrates, seeds, and fruits. Mimicry is characteristic of this species.

It is a noisy bird. Its song consists of a wide variety of melodic and mechanical-sounding noises.

Titmice (*Cyanistes caeruleus* L.) is a small bird in the family *Paridae*. It has blue and yellow plumage and is small. It is usually a resident and non-migratory bird that dwells in deciduous or mixed forests with a high proportion of oak. It usually nests in tree holes. This bird prefers insects, spiders, and seeds for its diet.

Warbler (*Luscinia luscinia* L.) is one of the most famous species of songbirds. This is a moisture-loving bird that often lives in floodplain forests. A song is a collection of repeated whistles and clicks.

The clutch contains 4-6 greenish or bluish eggs. It feeds on spiders, insects, worms, and berries.

Waxwing (*Bombycilla garrulus* L.) is a bird that breeds in the northern forests. It has mainly buff-grey plumage and a pointed crest. Its wings have white and yellow patterns, and some feather tips have a red-waxy appearance. The female is similar to the male.

The birds build a lined cup-shaped nest in a tree or bush. The clutch has 3–7 eggs.

They are primarily fruit eaters, like rowanberries but also consume insects.

Woodpeckers are part of the big family *Picidae*. Most species live in forest habitats. The woodpecker plumage varies from drab to conspicuous. Many species have a crest on their crowns. Woodpeckers are sexually dimorphic. Woodpeckers have strong bills that they use for drumming on trees, and long, sticky tongues for extracting food. Most woodpeckers live solitary. Woodpeckers are diurnal, roosting and nesting inside crevices and holes.

They mostly forage for insect prey on the trunks and branches of trees. Some species vary their diet with fruits, and tree sap.

Woodpeckers do not have such songs and calls as passerine birds. Thedrumming serves for the mutual recognition of conspecifics and plays a part in courtship rituals.

Wrens (*Troglodytes troglodytes*) is a small insectivorous bird. It is brownish above, and buff-brown below. It has a very short tail, a short neck and a long thin bill. The sexes are alike.

It occupies a variety of habitats. It inhabits open locations with clumps of brambles or gorse.

The nest has a side entrance and is built of grass, lichen moss, and dead leaves. A clutch of 5-6 eggs. There are two broods in a year.

Wrens are highly polygamous. Insects form the bulk of the diet.

12.2. Controlling pests with bats

Bats are one of the ranks of nocturnal mammals. Bats have unique biological features and a high vulnerability. Every second species of bat in the fauna of Ukraine is listed in the Red Book.

About 80 % of bats are insectivores, others eat fruits and flower nectar. Bats use ultrasound to hunt. With its help, they orient themselves and catch insects.

Bats are an integral part of ecosystems. Each night, a bat can eat from one to 10 grams of insects. A colony of *Nyctalus noctula* of 50 individuals can eat up to 50 kg of insects per year. Bats are the only night-flying predators that target moths, beetles, mosquitoes, mayflies, and leafhoppers. A little brown bat can catch 600 mosquitoes per hour.

Bats in temperate areas of the world are insectivorous. About 70 % of the bats' diet consists of plant-eating insects. A single bat can eat about 6,000-8,000 insects a night. Female bats that are nursing can even eat up to their weight i nightly. If bats were excluded, insect amount went up 153%.

In the composition of the fauna of Ukraine and adjacent territories, five large systematic groups represent bats: *Rhinolophidae* (species: *Rhinolophus hipposideros*, *R. ferrumequinum*, *Rhinolophus euryale*, *Rhinolophus mehelyi*); *Miniopterinae* (species: *Miniopterus schreibersii*); *Myotini* (species: *Myotis blythii*, *Myotis myotis*, *Myotis bechsteinii*, *Myotis nattereri*, *Myotis emarginatus*, *Myotis brandtii*, *Myotis mystacinus*, *Myotis aurascens*, *Leuconoe daubentonii*, *Leuconoe capaccinii*, *Leuconoe dasycneme*); *Plecotini* (species: *Plecotus auritus*, *Plecotus austriacus*, *Barbastella barbastellus*); *Vespertilionini* (species: *Nyctalus leisleri*, *Nyctalus noctula*, *Nyctalus lasiopterus*, *Pipistrellus kuhlii*, *Pipistrellus nathusii*, *Pipistrellus pipistrellus*, *Pipistrellus pygmaeus*, *Hypsugo savii*, *Vespertilio murinus*, *Eptesicus serotinus*, *Eptesicus nilssonii*).

12.3. Plants to attract birds

There are many ways to promote the effectiveness of birds as predators of harmful insects. It would be nice to encourage birds to take up residence in a definite area. It is possible to choose the species composition of trees and shrubs, attractive to certain species of birds

Food and water for birds. Trees and shrubs are home to insects that birds can feast on. In addition, trees and shrubs produce berries and fruits that can be critical for birds. Some flowering shrubs produce nectar that nectarivorous birds will enjoy, and some birds will snack on spring buds. In winter, shrubs with cones provide needed seeds for winter birds. Larger shrub and tree leaves will collect small amounts of water that different birds may sip.

Shelter for birds. Dense crowns provide shelter for birds, particularly thorny shrubs that can deter predators. Birds may rub against damp leaves for a bath.

Trees and shrubs are a source of summer shade for many birds, and evergreen trees and shrubs are ideal winter shelters as well.

Nesting sites. Many birds nest in trees and shrubs, particularly dense that provide good shelter and protection from neighborhood predators.

The plants that provide valuable food for a wide range of bird species:

Cornus spp. *Cornus* provides good cover and nesting sites as well as foraging for insectivorous birds. *Cornus* fruits are a favourite food of titmouse, oriole, robins, woodpeckers, sparrows, and finches.

Cotoneaster is one of the best shrubs that can provide food to different birds, and shelter some of them. Birds that love *Cotoneaster*: robins, waxwings, blackbirds, bullfinches.

Crataegus spp. The shiny clusters of haws can stay on hawthorn trees until spring. They are the favourite berries of blackbirds, fieldfares, chaffinches, and starlings.

Ilex spp. Birds that love *Ilex* are thrushes.

Hedera. The black berries appear in the middle of winter. Thrushes, waxwings, starlings and jays, and finches devour them. The brunches and leaves provide nesting and roosting shelter for birds.

Lonicera spp. In autumn, it provides berries and shelter. Fruits are eaten by robins, thrushes, chickadees and bullfinches. In summer, its scented flowers attract insects and so provide food for a different range of birds.

Mahonia. Their berries eaten by finches, and robins.

Malus spp. attracts robins, waxwings, thrushes, finches. This tree species provides nest and cover.

Morus spp. attracts robins, waxwings, and numerous other songbirds. It can also serve as a nesting point for some birds.

Rhamnus spp. Black fruits in fall attract thrushes, jays, quail, robins, waxwings, pigeons, and finches.

Rhus typhina attracts thrushes, robins, chickadees, woodpeckers, quails, finches, and starlings.

Ribes spp. Berries attract thrushes, quails, robins, and finches.

Rosa spp. Rosa hips are relished by siskin, goldfinches, and others. Rosa is an excellent nesting cover for quails and other ground-nesting birds. Fieldfares and thrushes take some of the largest rose hips. The smaller hips of the *Rosa spp,* are eaten by a wider range of birds and stay juicy until late winter.

Rubus spp. Their fruits attract wren tits, waxwings, and robins.

Salix spp. Warblers, thrushes, finches, and sparrow relish the unripe capsules. Salix is one of the most desirable plants for songbirds.

Sambucus spp. is the best plant for attracting birds. Pigeons, woodpeckers, doves, finches, wren-tits, quails, robins, thrushes, nuthatches, titmice, goldfinches, orioles, and waxwings eat berries. This species may provide good cover and is excellent for nesting.

Sorbus spp. fruits attract birds such as blackbirds and starlings.

Symphoricarpos spp. The plant forms thickets that provide cover for nesting sites. Berries are white and showy in winter. Thrushes, robins, and waxwings eat them.

Vaccinium spp. attracts thrushes, and robins.

Viburnum spp. bears heavy clusters of glossy berries from November through to March. Thrushes and bullfinches like them.

***Vitis spp.* is** an excellenet nest site, nest material (shredding bark) and cover. *Vitis* attracts thrushes, orioles, robins, pigeons, waxwings and woodpeckers.

Uniperus virginiana attracts waxwings and provides excellent nest sites and cover.

Quercus spp. are great bird plants. They provide many nest sites, and holes. Acorns are the staple food of the woodpeckers, orioles, titmouse birds, nuthatches, and all insectivorous birds.

CHAPTER 13
PLANT QUARANTINE

13.1. History of plant quarantine

Quarantine is derived from the Latin word "*quarantum*". It means a forty-day period.

An increase in the international trade of agricultural products is connected with the risk of introducing harmful species. These species can threaten agricultural production and biodiversity in a specific country. The spread of nonindigenous species may occur very slowly or vice versa.

Quarantine is a legal regime, which provides for a system of state measures aimed at protecting plants, raw materials, and other cargo from quarantine facilities. Plant quarantine includes all activities designed to prevent the spread of quarantine pests or to ensure their official control.

Insects, nematodes, fungi, bacteria, viruses, weeds and other organisms are known can attack forests. These pests reduce the quantity and spoil the quality of the product including wood.

The following plant or their products must be applied to quarantine:

1. Live plants.
2. Seedlings, seeds, bulbs.
3. Vegetables and fruits.

4. Cut flowers and cut branches.

4. Dried plants, spices (herbs and spices).

5. Grains, beans

6. Wood material.

7. Medicinal ingredients.

The story of plant quarantine and plant protection begins more than 600 years ago.

Historical events which led to the need for plant quarantine:

1. The first legal restrictions that hindered the spread of human disease.

2. It was the outbreak of bubonic plague. The Venetian Republic excluded infected and suspected ships and made the first quarantine in 1403.

3. Travellers from Egypt and Levant were isolated in a detection hospital for 40 days.

4. The first plant quarantine law was enacted in Rouen (France) in 1660. It was the ordering of barberry plant eradication around grain fields.

5. The first British legislation against animal disease was an Act of granting emergency powers for the destruction of all rinderpest beasts (1866).

6. An embargo was passed in Germany to prevent the introduction of the Colorado potato beetle (Leptinotarsa decemlineata) from the USA in 1873.

7. The first legislative measures against plant disease were promulgated in North America in 1875.

8. The United Kingdom Destructive Insects Act was passed to prevent of the importation of the Colorado potato beetle in 1877.

9. The first plant quarantine measure was initiated in USA by setting up a seaport inspection station at San Padro (California) in 1891.

10. The USA Congress enacted the Federal Plant Quarantine Act, which prohibits the entry of plants into the United States (1912).

11. Five countries signed the first international plant protection convention in 1881.

12. This convention remained in force until 1951 when International Plant Protection Convention under FAO (Food and Agriculture Organization) was established in Rome. This agreement was constituted with the purpose of securing common and effective action to prevent the introduction and spread of pests and diseases of plants and plant products.

Plant pathogens and insects harmful to plants collectively referred to as pests, continue to threaten biodiversity. International collaboration and regulatory systems to prevent the spread of plant pests started formally in 1878. Five countries worked together at first. There are 172 countries, which are contracting parties to the International Plant Protection Convention nowadays. The work aims to prevent the introduction and spread of pests and to promote appropriate measures for their control.

Phytosanitary legislation is present in these countries. It serves several purposes, the most important one enabling countries to protect their agricultural resources and natural environment from the introduction and spread of pests. It also allows countries to implement their international obligations and foster cooperation and research in the way of plant protection.

Forms of quarantine can be grouped into three classes (Fig. 13.1):

1. International quarantine is legislation to prevent the introduction of new pests from foreign countries.

2. Domestic quarantine is legislation to prevent the spread of already established pests from one part of the country to another.

3. Farmer's quarantine is legislation to enforce farmers to apply effective control and measures in relation to already established pests.

Quarantine objects are pests, pathogens of plants, or weeds, that are absent or limited in a certain country, but they can cause significant damage to plants or plant products. The quarantine objects (Fig. 13.2) include insects, pathogens (fungal, bacterial, and viral), nematodes, and weeds.

The basic purposes of plant quarantine are:

- protection of the country's territory from bringing of quarantine objects from abroad or the quarantine zone;
- timely discovery, localization, and liquidation of quarantine objects;
- implementation of the state control over observance of the special quarantine regime as well as the implementation of the plant quarantine measures.

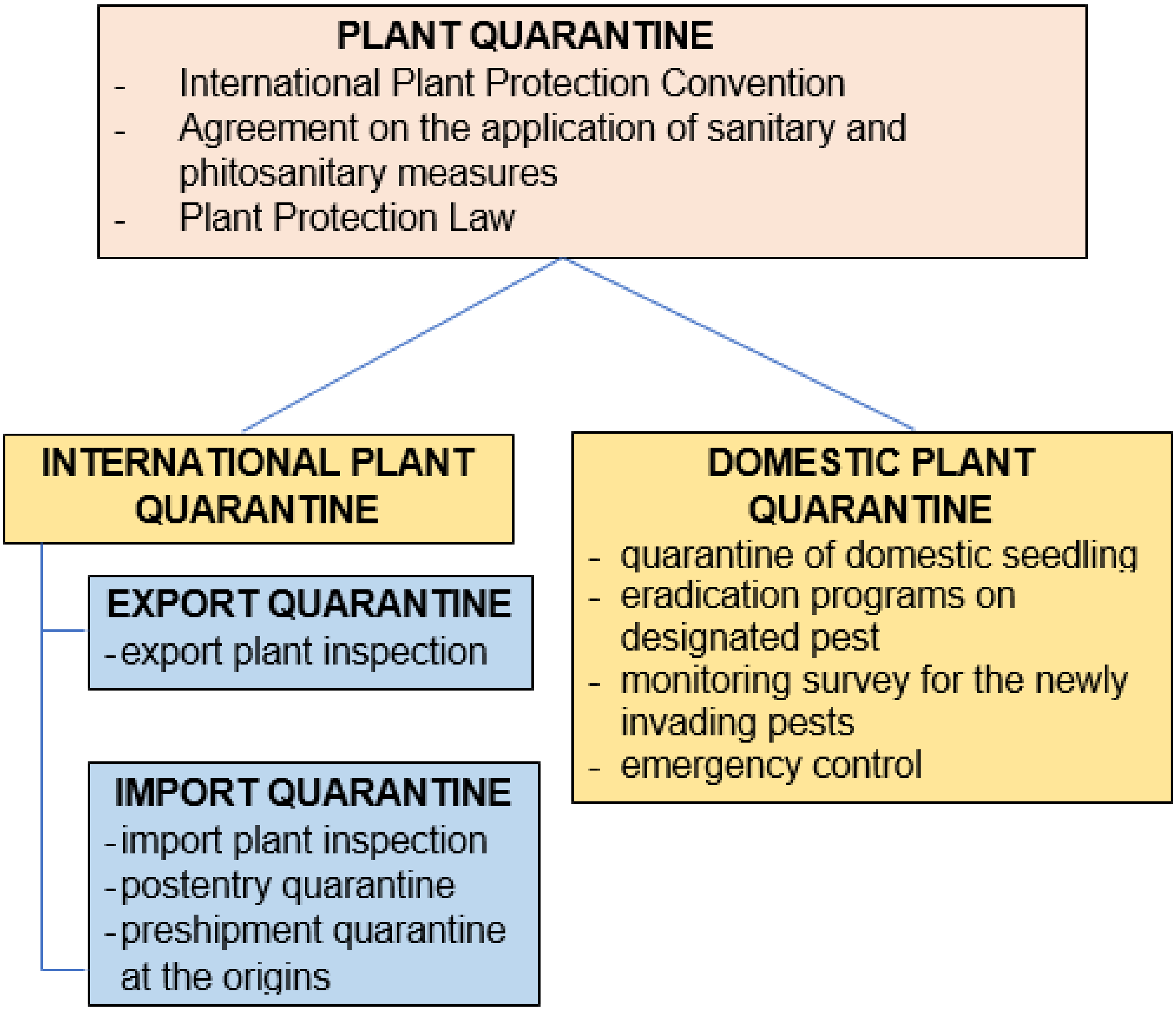

Fig. 13.1. The plant quarantine system

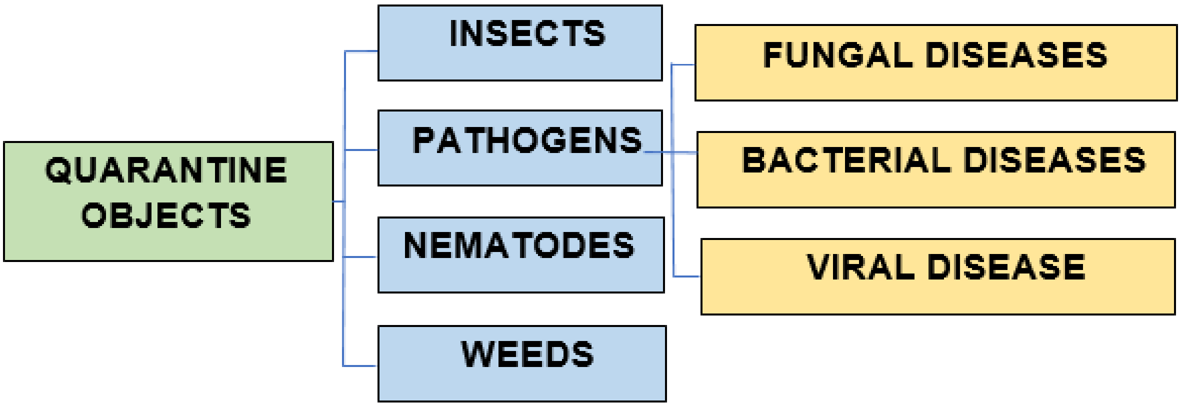

Fig. 13.2. The quarantine objects

Plants and other plant products are imported from foreign countries by personal luggage, parcel post, cargo, etc. They are subject to plant quarantine. Procedures of plants and their products quarantine are shown in Fig. 13.3.

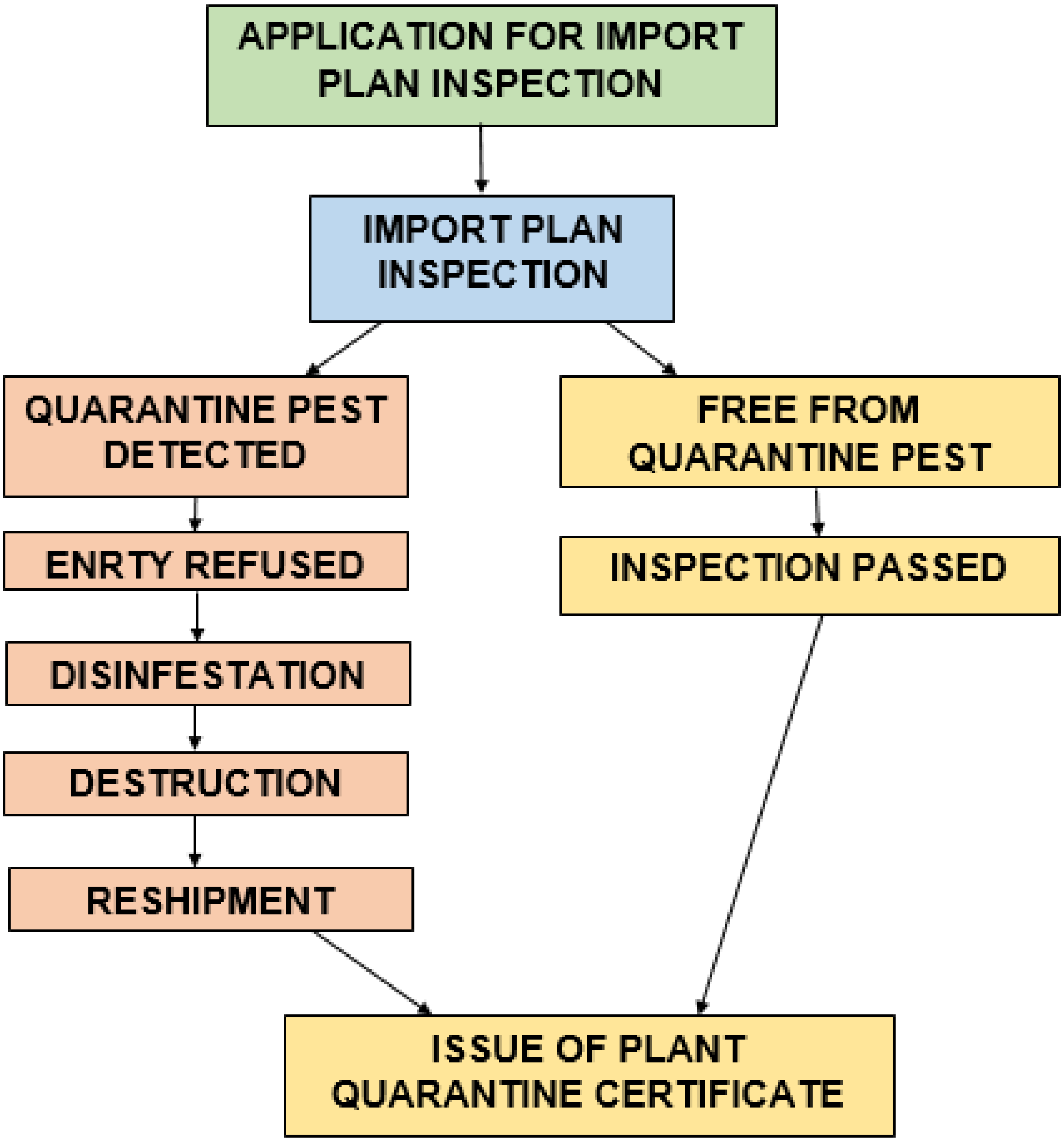

Fig. 13.3. Procedures of plants and their products quarantine

In all places of crossing the state border, a quarantine inspection of imported products is contact, with which unwanted objects can be brought into the country. Quarantine monitoring is constantly held inside the country in order to detect quarantined species. The procedure of plant quarantine includes determination the condition of the foci of quarantine objects, their dynamics, and measures for the extermination of quarantine species.

Quarantine Certificate is an official document required during the shipping cargo.

13.2. The Law of Ukraine on plant quarantine

An increase in the international trade of agricultural products is connected with the risk of introducing harmful species. These species can threaten agricultural production and biodiversity in a specific country. The spread of nonindigenous species may occur very slowly or vice versa.

The consequences of such invasions are unpredictable. Some of the non-native pests may have drastic ecological impacts. Native species can disappear due to competition for space or nutrients. The establishment of invasive organisms may have social and economic effects.

Up to 200 species that are not common in Ukraine are detected annually in imported agricultural products. For this reason, phytosanitary control enhancement is important in Ukraine. All materials and objects that cross the state border of Ukraine and the borders of the special quarantine zones to quarantine are subject to phytosanitary control.

The Law "Concerning the Quarantine of Plants" is active in Ukraine. There are asserts organizational and economic backgrounds of the plant quarantine, the authority of governing institutions, rights and an obligation of legal entities and individuals, about the prevention of emergence and spread of unwanted or harmful organisms at the territory of Ukraine. This Law forms a way of the legislation of Ukraine in relation to plants' life and health protection. Special quarantine regime – a special legal regime of activities of the state bodies, enterprises, organizations and institutions aimed at the localization and liquidation of the found quarantine objects. The temporary introduction of restrictions provided for by the Law on the citizens' rights is permitted during the special quarantine regime.

A quarantine zone is a territory where a special quarantine regime is held established due to the revealed quarantine objects. Aim of plant quarantine in preventing the appearance and spread of insects, plant pathogens, and weeds, nematodes, and other alien agents from borders.

The list of regulated pests in Ukraine includes compounds:

- A-1 (quarantine pests that are absent from the territory of Ukraine);
- A-2 (quarantine pests that are locally presented in Ukraine);
- regulated non-quarantine pests.

The national lists of regulated pests are subjected to national phytosanitary regulation. There are 238 species included.

Quarantine pests that are absent from the territory of Ukraine

Plant diseases (pathogens)

Bacteria

Burkholderia caryophylli (Burkholder) Yabuuchi et al.

Corynebacterium tritici (Hutch) Burkh.

Erwinia stewartii (Smith) Dye.

Ralstonia solanacearum (Smith) Yabuuchi et al.

Xanthomonas campestris pv. hyacinthi (Wakker) Dovson.

X. oryzae pv. oryzae (Ishyama) Swings et al.

X. oryzae pv. oryzicola (Fang et al.) Swings et al.

Xylella fastidiosa Wells et al.

Xylophilus ampelinus (Panagopoulos) Willems et al.

Fungi

Ceratocystis fagacearum (Bretz) Hunt.

Cronartium coleosporioides J.C. Arthur.

C. comandrae Peck.

C. comptoniae J.C. Arthur.

C. fusiforme Hed. & Hunt ex Cum.

C. himalayense Bagchee.

C. kamtschaticum Jorstad.

C. quercuum (Berkeley) Miyabe ex Shirai.

Didymella ligulicola (K.F. Baker, Dimock & L.H. Davis) von Arx.

Endocronartium harknessii (J.P. Moore) Y. Hiratsuka.

Monilinia fructicola (Winter) Honey.

Mycosphaerella laricis-leptolepidis K. Ito, K. Sato & M. Ota.

M. populorum G.E. Thompson.

Ophiostoma wageneri (Goheen & Cobb) Harrington.

Phialophora cinerescens (Wollenweber) van Beyma.

Phellinus weirii (Murrill) R.L. Gilbertson.

Phoma andigena Turkensteen.

Phyllosticta solitaria Ellis & Everhart.

Plasmopara halstedii (Farlow) Berlese et de Toni.

Puccinia horiana P. Hennings.

Stenocarpella macrospora (Earle) Sutton.

S. maydis (Berkeley) Sutton.

Thecaphora solani (Thirumulachar & O'Brien) Mordue.

Tilletia indica Mitra.

Viruses

Chrysanthemum stem necrosis tospovirus.

Maize dwarf mosaic virus.

Potato Andean latent tymovirus.

P. A. mottle comovirus.

P. black ringspot nepovirus.

P. Ttrichovirus.

P. yellow dwarf nucleorhabdovirus.

P. yellow vein crinivirus.

Insects

Aeolesthes sarta Sols.

Aleurocanthus spiniferus Quaint.

A. woglumi Ashby.

Anoplophora chinensis Forst.

A. glabripennis Motsh.

Bactrocera dorsalis Hend.

B. zonata Saund.

Bemisia tabaci Gen.

Callosobruchus chinensis L.

C. maculatus Fabr.

Carposina niponensis Wals.

Caryedon gonagra Fabr.

Ceratitis capitata Wied.

C. cosyra Walk.

C. rosa Karch.

Conotrachelus nenuphar Herb.

Cydia packardi Zell.

C. prunivora Wals.

Dendrolimus sibiricus Tschetv.

Diabrotica barberi Smith & Lawr.

D. speciosa Germ.

D. undecimpunctata Man.

Dinoderus bifoveolatus Woll.

Ips hauseri Reit.

I. subelongatus Motsch.

Liriomyza huidobrensis Blanc.

L. sativae Blanc.

L. trifolii Burg.

Monochamus alternatus Hope.

M. carolinensis Oliv.

M. marmirator Kirb.

M. mutator LeQont.

M. nitens Bat.

M. notatus Drury.

M. obtusus Cas.

M. scutellatus Say.

M. titillator Fabr.

Naupactus leucoloma Boh.

Pissodes nemorensis Germ.

P. strobi Peck.

P. terminalis Hop.

Popillia japonica Newm.

Premnotrypes latithorax Pier.

P. suturicallus Kusch

P. vorax Hust.

Rhagoletis pomonella Walsh.

R. cingulata Loew.

R. indifferens Cur.

Scolytus morawitzi Sem.

Sinoxylon conigerum Gers.

Spodoptera eridania Cram.

S. frugiperda Smith.

S. littoralis Boisd.

S. litura Fabr.

Tetropium gracilicorne Reit.

Thrips palmi Karn.

Trogoderma granarium Ev.

Xylotrechus altaicus Geb.

X. namanganensis Heyd.

Nematodes

Bursaphelenchus xylophilus (Steiner and Buhrer) Nickle.

Globodera pallida (Stone) Behrens.

Heterodera glycines Ichinohe.

Meloidogyne chitwoodi Golden, O'Bannon, Santo & Finley.

M. fallax Karssen.

Nacobbus aberrans (Thorne) Thorne & Allen.

Weeds

Ambrosia psilostachya D.C.

A. trifida L.

Helianthus californicus D.C.

H. ciliaris D.C.

Iva axillaris Pursh.

Solanum carolinense L.

S. elaeagnifolium Cav.

S. triflorum Nutt.

Striga lutea Lour.

S. euphrasioides Benth.

S. hermontica Benth.

Quarantine pests that are locally presented in Ukraine

Plant diseases (pathogens)

Bacteria

Erwinia amylovora (Burrill) Winslow et al.

Fungi

Mycosphaerella linicola Naumov.

Synchytrium endobioticum (Schilbersky) Percival.

Viruses

Beet necrotic yellow vein furovirus.

Plum pox potyvirus

Insects

Diabrotica virgifera virgifera Le Conte.

Frankliniella occidentalis Perg.

Hyphantria cunea Drury.

Phthorimaea operculella Zell.

Nematodes

Globodera rostochiensis (Wollenweber) Behrens.

Weeds

Acroptilon repens L.

Ambrosia artemisiifolia L.

Cuscuta alba J. Presl et C. Presl.

C. approximata Bab.

C. australis R. Br.

C. basarabica Buia.

C. campestris Yunck.

C. epilinum Weihe.

C. epithymum L.

C. europaea L.

C. gronovii Willd.

C. lupuliformis Krock.

C. monogyna Vahl.

C. suaveolens Ser.

C. trifolii Bab.

C. viciae Schultz.

C. Lehmanniana Bge.

Sorghum halepense (L.) Pers.

Solanum rostratum Dunal.

Regulated non-quarantine pests

Plant diseases (pathogens)

Bacteria

Clavibacter michiganensis subsp. sepedonicum (Spieckermann)

Xanthomonas arboricola pv. pruni (Smith) Vauterin et al.

X. vesicatoria (ex Doidge) Vauterin et al.

Fungi

Apiosporina morbosa (Schweinitz) von Arx.

Ceratocystis fimbriata Ellis & Halsted f.sp. platani Walter.

Chrysomyxa arctostaphyli Dietel.

Colletotrichum acutatum Simmonds.

Gymnosporangium asiaticum Miyabe ex Yamada.

G. clavipes (Cooke & Peck) Cooke & Peck.

G. globosum (Farlow) Farlow.

G. juniperi-virginianae Schwein.

G. yamadae Miyabe ex Yamada.

Melampsora farlowii (J.C. Arthur) J.J. Davis.

M. medusae Thümen.

Mycosphaerella dearnessii M.E. Barr.

M. gibsonii H.C. Evans.

M. pini E. Rostrup.

Phytophthora fragariae Hickman.

Phymatotrichopsis omnivora (Duggar) Hennebert.

Viruses

American plum line pattern ilarvirus.

Apple mosaic ilarvirus

Cherry leafroll nepovirus

C. little cherry closterovirus (non-European)

C. rasp leaf nepovirus

Chrysanthemum stunt pospoviroid

Impatiens necrotic spot tospovirus

Peach rosette mosaic nepovirus

Potato spindle tuber pospiviroid

Raspberry ringspot nepovirus

Strawberry latent C virus

Tobacco ringspot nepovirus

Tomato ringspot nepovirus

T. spotted wilt tospovirus

Insects

Acleris gloverana Wals.

A. variana Fern.

Aculops fuchsiae Keifer.

Amauromyza maculosa Mall.

Anthonomus bisignifer Schen.

A. quadrigibbus Say.

A. signatus Say.

Aonidiella aurantii Mask.

A. citrina Coq.

Cacoecimorpha pronubana Hubn.

Choristoneura conflictana Walk.

C. fumiferana Clem.

C. occidentalis Freem.

C. rosaceana Har.

Diaphorina citri Kuw.

Dryocosmus kuriphilus Yas.

Epitrix cucumeris Har.

E. tuberis Gent.

Limonius californicus Mann.

Liriomyza bryoniae Kalt.

Listronotus bonariensis Kus.

Lepidosaphes ussuriensis Bork.

Lopholeucaspis japonica Cock.

Maconellicoccus hirsutus Green.

Malacosoma americanum Fabr.

M. disstria Hub.

M. parallella Staud.

M. vitis Philippi.

M. communis Gyll.

Numonia pyrivorella Mats.

Oligonychus perditus Pritchard & Baker.

Opogona sacchari Boj.

Parasaissetia nigra Niet.

Pseudaulacaspis pentagona Targ.

Quadraspidiotus perniciosus Comst.

Rhizoecus hibisci Kaw. & Tak.

Scirtothrips aurantii Faure.

S. citri Moul.

S. dorsalis Hood.

Sirex ermak Sem.

Tecia solanivora Pov.

Toxoptera citricida Kirk.

Trioza erythreae Del Guer.

Tuta absoluta Meyr.

Unaspis citri Comst.

Viteus vitifolii Fitch.

Zabrotes subfasciatus Boh.

Nematodes

Aphelenchoides besseyi Christie.

Ditylenchus destructor Thorne.

D. dipsaci Filipjev.

Radopholus citrophilus Huettel et al.

R. similis (Cobb) Thorne.

Weeds

Ailanthus altissima (Mill.) Swingle.

Bidens pilosa L.

B. bipinnata L.

Ipomea hederaseae L.

I. lacunosa L.

Polygonum pensylvanicum L.

Raimania laciniata Hill.

METHODICAL RECOMMENDATIONS FOR PERFORMANCE PRACTICAL AND INDEPENDENT WORKS

PRACTICAL WORK 1
CATEGORIES OF FOREST PESTS

The purpose of practical work. To learn different types of forest pests.

Theoretical provisions.

Forests are complex ecosystems that provide a variety of valuable products, such as timber, fuelwood, non-wood forest products, that contribute to the livelihoods of rural communities. They also provide vital ecosystem services, such as combating desertification, protecting watersheds, maintaining biodiversity, deposit of carbon sequestration and play an important role in preserving social and cultural values. It is critically important to protect forest resources from disturbances such as fire, pollution, invasive species, insects and diseases.

While pests are integral components of forest ecosystems, they have considerable influence on the health of forests and plants outside forests. They can adversely affect forest plants' survival, growth, and vigour, the yield and quality of wood and non-wood products, wildlife habitat, human recreation, aesthetics and cultural values.

Pest management should be aimed that the risks and impacts of unwanted disturbances are minimized. Measures to protect forests from pests are an integral part of sustainable forest use. Effective pest management in forests requires reliable information about the pests, their biology, ecology, distribution, their impacts on natural ecosystems, and possible methods of control.

Forest pests are biotic disturbances, meaning that living organisms are the source of tree or forest diseases. For an understanding description, all pests have been classified into categories.

Forest pests are living organisms (plants, animals and pathogenic agents) detrimental to the forest health or forest products quality. Forest pests include weeds, insects, diseases, rodents, and nematodes.

*A **weed** is a plant considered undesirable and non-typical in a forest.*

Insects*. Insects r**epresent the wider portion of forest pests. ***Insects have segmented bodies, jointed legs, and exoskeletons.

Forest pathogens are represented by living beings not classified as animals such as bacteria, fungi, viruses, etc. causing forest diseases.

Other forest pests are represented by non-insect pests such as certain nematodes and other species that can spread diseases among trees being hosted on a number of beetles or other insects. The definition also includes mites, mammals, birds, and plants.

According to the Global review of forest pests and diseases by Food and Agriculture organization of the United Nations almost 77 % of the forest pests reported from the overview countries were insect pest species. All regions reported significantly more insect pests than other pest types. Sixteen percent of the pest species were pathogens and the remaining 7 percent were other pests. Insects tend to be easier to trap than other pests and easier to identify as the cause of tree damage, although identification still requires specialized training and expertise.

The impacts of pathogenic diseases on forest trees, such as destruction of internal wood, reductions in growth, or delayed regeneration, are often subtle and difficult to detect. It can be difficult to determine the causative agent of these impacts. Likewise, the impacts of other pests such as nematodes, mites, mammals and parasitic plants on forest trees are not easy to detect. Over 73 % of pests in planted forests and 91 % in naturally regenerated forests were indigenous species. Almost 62 % of forest pests were recorded on broadleaf tree species, over 30 % on conifers and almost 8 % on both host types. In all regions, pests were recorded more often on broadleaf trees than conifers.

Task. Read the regulations (supplement A, B, and C). Describe different types of forest pests and fill the table 1 and 2. Do the next steps:

1. Provide examples and describe five species of weeds, insects, rodents, fungi, nematodes.
2. Give examples of the consequences of pest activity.

Table 1. Pest in the forest

Pests	Species
1. Insects	1.
	2.
	3.
	4.
	5.
2. Fungi	1.
	2.
	3.
	4.
	5.
3. Viruses	1.
	2.
	3.
	4.
	5.
4. Bacteria	1.
	2.
	3.
	4.
	5.
5. Weeds	1.
	2.
	3.
	4.
	5.
6. Rodents	1.
	2.
	3.
	4.
	5.
7. Nematodes	1.
	2.
	3.
	4.
	5.

Table 2. Consequences of pest activity (foto)

Foto 1. Sucking damage and deformed leaves	Foto 2. Discolored leaves
Foto 3. The chewed and skeletonized leaves	Foto 4. Galls
Foto 5. Leaf miners' damage	Foto 6. Leafroller damages
Foto 7. Punctures	Foto 8. Stem damaging insects
Foto 9. Insects of forest crops	Foto 10. Root damaging insects

References:

[4, 8, 9, 19, 22, 23]

Questions:

1. What are ecosystem services provided by forest?
2. What consequences of pest activity do you know?
3. What the most common pests in forest do you know?

4. Give the examples of biotic, abiotic and anthropogenic factors.
5. What is the great aim of Pest management?
6. Give a global review of forest pests.
7. Give examples of the other forest pests.
8. Why it is difficult to detect the impacts of pathogenic diseases on forest trees?
9. How many indigenous species of pests are recorded in planted forests and in naturally regenerated forests?
10. How many forest pests were recorded on broadleaf tree species and conifers?

PRACTICAL WORK 2
PESTS ON THE DIFFERENT PARTS OF TREES

The purpose of practical work. To learn pests on (in) different parts of trees.

Theoretical provisions.

Trees are susceptible to pests. The diseases and insects can reduce productivity, wood quality, decorativeness and attractiveness or kill the tree. Many environmental factors can cause a tree to be stressed. Pest outbreaks are often seasonal, regional, and species-specific.

Drought, overwatering, and damage to stem or roots are the most common causes. Stem damage invites infection by creating points of entry for pathogens. Root damage creates points of entry for pathogens and reduces the trees ability to collect water that puts the tree under stress, thus making it more susceptible to infection.

Drought, whether from lack of rainfall, overwatering, or root damage reduces the ability of a tree to isolate infections and prevent their spread through the tree.

The parts of a tree can be broken down into the roots, trunk, bark, branches, crown, leaves, and periodically flowers and/or fruit. Each part of a tree has a different function from the roots soaking up vital water and nutrients to the fruit continuing the growth of the species.

Crown *is a* part of the tree that consists of leaves, branches.

***Leaves* are** food factories of the tree. They contain chlorophyll which gives leaves their green color and is responsible for photosynthesis. During photosynthesis, leaves use sun energy to convert carbon dioxide from the atmosphere and water from the soil into sugar and oxygen. The sugar (which is the tree's food) is either used or stored in the branches, in the trunk, or in the roots. The oxygen is released into the atmosphere.

Trunk (Stem) supports the leaves and the branches of the tree and contains the xylem, the cambium, the phloem, and the heartwood.

Heartwood is inner core of dead wood that supports the tree. As a tree grows, older xylem cells in the centre of the tree become inactive and die, forming the heartwood.

The ***roots*** of a tree are the contact point between the soil and the tree. They absorb the water and nutrients that the xylem carries to the rest of the tree. These roots are generally large, numerous, and underground. They help to support the tree, as it grows because trees can become very large and heavy.

In botany, a ***fruit*** is the seed-bearing structure in flowering plants that is formed from the ovary after flowering. They can be cones, acorns, juicy fruits, berries and seeds. Symptoms of fruit diseases are mummification, rot, rust, spots, mold

Ornamental plants are plants that are grown for ornamental purposes in gardens and landscape design projects. Ornamental trees also suffer from pests.

Commonly, ornamental garden plants are grown for the display of aesthetic features including flowers, leaves, scent, overall foliage texture, fruits, stem and bark, and aesthetic form. In some cases, unusual features may be considered to be of interest.

Task. Read plant, fungi, insects, bacteria taxonomy (supplement D, E, F, G). Describe types of pests on different parts of trees (including ornamental plants) and fill the table 3.

Table 3. Ecological groups of forest plant pests

Parts of tree	Insects	Nematodes	Diseases	Rot	Fungi
Reproductive plant part					
Fruit					
Leaves					
Needles					
Bark					
Bast wood					
Root					

Do next step:

1. Provide examples and describe pests on (in) fruit, leaves, and needles, reproductive plant parts, in bark, phloem, wood, and roots.

2. Describe which groups of pests can complement each other.

References:

[2, 7, 14, 21]

Questions:

1. Give the damage classes for foliage (needles/leaves).
2. What is the concept of pathological process in plants?
3. Identify stress factors for roots.
4. How are logging residues should be removed?
5. Explain the negative impact of tapping on the forest.
6. Explain the negative impact of cattle grazing on the forest.
7. What does an excess of nutrients in the soil lead to woody plants?
8. What is the harmfulness of early autumn and late spring frosts?
9. How does the pathogen penetrate into the plant?
10. How it is possible to warn spread of pests to fruits?
11. Make a list of ornamental woody plant diseases in a particular region.

12. Make a list of ornamental woody plant insects in a particular region.
13. What factors can limit pest populations in the garden?
14. What is the meaning of plant resistance?
15. Give an overview of plant selection.
16. What stuff includes cultural controls?
17. What stuff includes mechanical and physical control?
18. What stuff includes biological control?
19. Give classifications of pesticides.
20. Give toxicity categories of pesticides.

PRACTICAL WORK 3
CLASSIFICATION OF INSECTS

The purpose of practical work. To learn classification of insects.

Theoretical provisions.

Insects are the most numerous group of the animal world, numbering about a million species. They have inhabited almost all living environments: terrestrial and aerial, soil, water, organisms of other creatures.

Depending on the nature of damage, phytophagous insects are divided into several groups. It is appropriate to divide into groups, depending on the organs and parts of plants damaged by phytophagous insects. According to this feature, the following groups of phytophagous insects are distinguished: needle- and leaf-eating, stem and root pests, insects of the aerial part of woody plants, etc. Damage by phytophagous insects causes a significant weakening of plants, a decrease in their ornamentality, bending of branches and stems, dry tops, and sometimes drying. When the needles are completely eaten, coniferous woody plants, as a rule, dry up.

Deciduous woody plants in favourable conditions, if the leaves are eaten once, renew them in the same year, however, when phytophagous insects eat leaves for several years, the plants begin to wither and dry up.

The hierarchy includes the universally accepted Linnean hierarchy categories: Species–Genus–Family–Order–Class–Phylum–Kingdom.

The class of Insects is divided into two subclasses – *Apterygota* and *Pterygota*, into two divisions – *Hemimetabola* and *Holometabola*.

With few exceptions, insects begin life as eggs. Development from eggs to adults is termed metamorphosis. *Hemimetabola* insects have incomplete metamorphosis. They change shape gradually as they grow (Fig. 1). They have three stages of development: the egg, nymph, and adult. Grasshoppers, termites, bugs, and lice are all of part of this group.

Insects with complete metamorphosis (*Holometabola*) go through four stages of development. None of the stages look at all like the others. These stages are referred to as egg, larva, pupa, and adult. Fleas, flies, beetles, bees, and moths all belong to this group (Fig. 2).

Insects have an exoskeleton, a hard outer layer made mostly of chitin which protects and supports the body. The insect body is divided into three parts: the head, thorax, and abdomen. The head is specialized for sensory input and food intake; the thorax, which is the anchor point for the legs and wings (if present), is specialized for locomotion; and the abdomen for digestion, respiration, excretion, and reproduction. Although the general function of the three body regions is the same across all insect species, there are major differences in basic structure, with wings, legs, antennae, and mouthparts being highly variable from group to group.

The cuticle protects insects from adverse conditions, prevents evaporation of water from the body, serves as a place of attachment of the middle of skeletal muscles, and increases resistance to deformation.

Tasks. Read classification of the insects (supplement H) and their phenology (supplement I). Describe types of insects on different parts of trees and fill the table 4. Do next step:

1. Give the classification of the insect orders that damage plants (references to sources are required).
2. Get acquainted in detail with *Orthoptera*, *Coleoptera*, *Trysanoptera*, *Hemiptera*, *Lepidoptera*, *Hymenoptera*, *Diptera*, give the main signs of their manifestation.

Describe body parts of insect (Fig. 3).

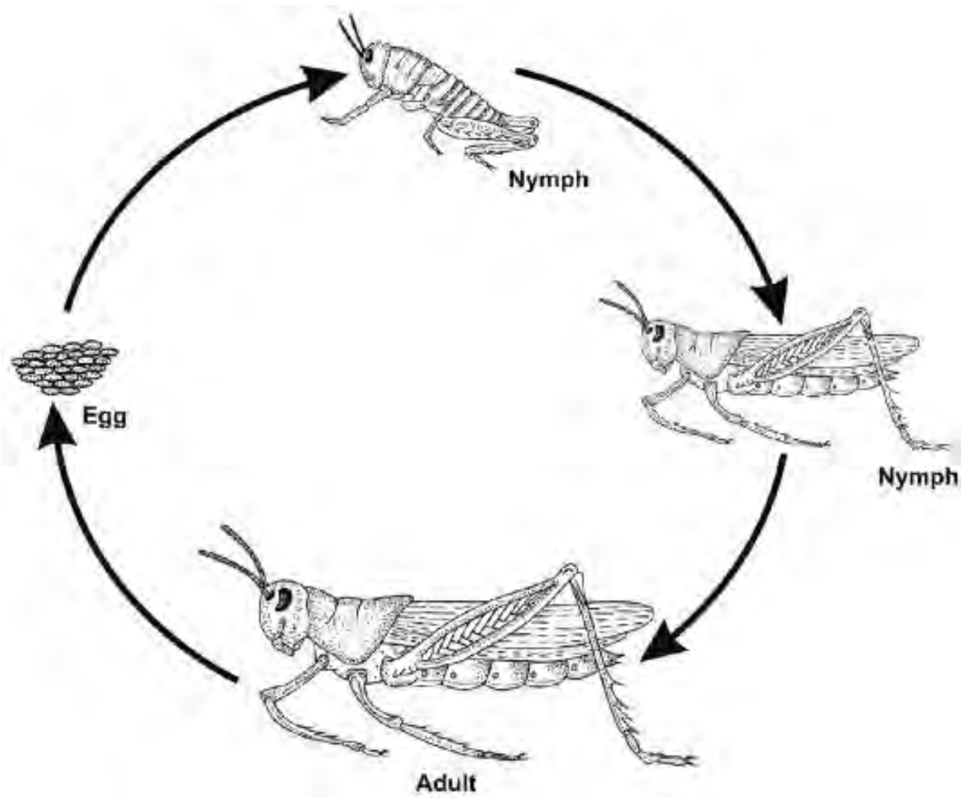

Figure 1. Hemimetabola

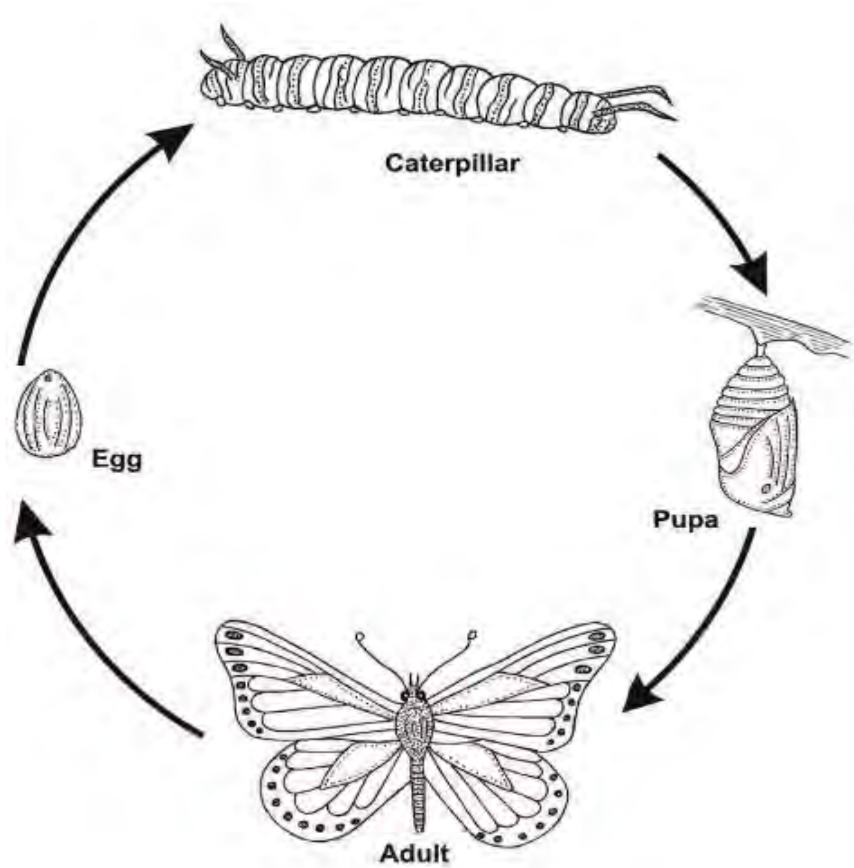

Figure 2. Holometabola

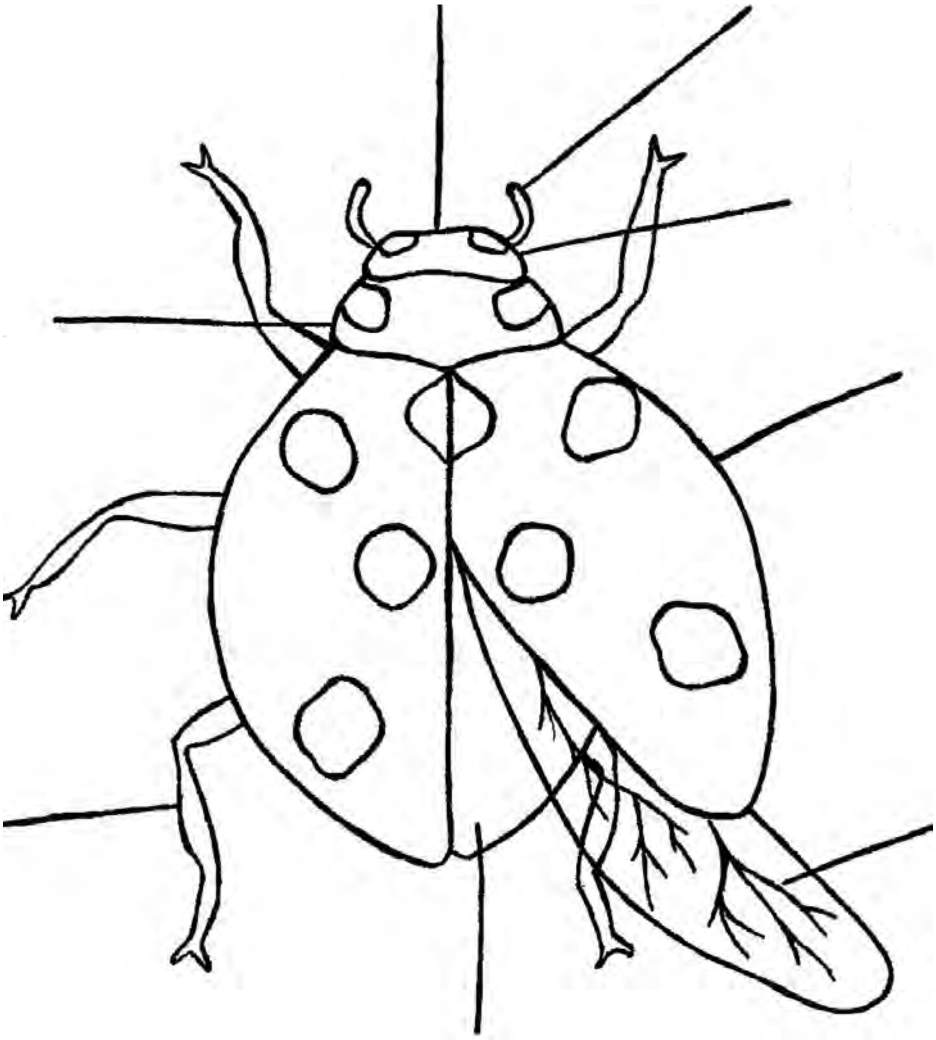

Figure 3. Body parts of insect

Table 4. Insects on different parts of forest plants

Order	Parts, organs, and tissues of tree					
	Reproductive plant part	Leaves	Needles	Bark	Phloem and wood	Root
Orthoptera						
Coleoptera						
Trysanoptera						
Hemiptera						
Lepidoptera						
Hymenoptera						
Diptera						

References:

[2, 27, 28, 29, 30,32]

Questions:

1. Define the species and population of insects.
2. What main stages refer to insects with incomplete transformation?
3. What main stages refer to insects with complete transformation?

4. Give examples of *Hemimetabola* and *Holometabola.*
5. What are the main characteristics of the *Coleoptera*?
6. What are the main characteristics of the *Lepidoptera*?
7. What are the main characteristics of the *Hymenoptera*?
8. What are the main characteristics of the *Diptera*?
9. What are the main characteristics of representatives of the *Hemiptera* order?
10. What are the main characteristics of the *Orthoptera*?

PRACTICAL WORK 4
INSECTS OF THE ABOVE GROUND AND UNDERGROUND PARTS OF THE PLANTS

The purpose of practical work. To learn insects of the above ground and underground parts of the plants.

Theoretical provisions.

Outbreaks of needle- and leaf-eating insects are cyclically repeated on large areas. Most of these insects belong to the order *Lepidoptera*: *Dendrolimus pini* L., *Malacosoma neustria* L., *Lymanthria monacha* L., *Lymanthria dispar* L., *Euproctis chrysorrhoea* L., *Calliteara pudibunda* L., *Leucoma salicis* L., *Panolis flammea* Schiff., *Bupalus piniarius* L., *Boarmia bistortata* Goeze, *Operophthera brumata* L., *Erannis defoliaria* CL., *Zeiraphera diniana* Gn., *Phalera bucephala* L., *Notodonta anceps* Goeze., *Tortrix viridana* L., *Archips crataegana* Hb., *Aporia crataegi* L., *Hyphantria cunea* Drury., *Acrocercops brongniardella* F., *Thaumetopoea processionea* L. Some of pest insects belong to the order of *Hymenoptera*: *Diprion pini* L., *Neodiprion sertifer* Geoffroy and *Coleoptera*: *Chrysomela populi* L.

Leaf pest insects. Pest insect species are the following: *Aphis pomi De Geer*, *Viteus vitifoliae, Phylloxera coccinea, Tetraneura ulmi,* ***Tetraneura coerulescens,*** *Hyalopterus pruni, Eriosoma lanigerum, Eriosoma ulmi* L., *Lachnus roboris* L., The most common among *Chrysomelidae* are: *Melasoma tremulae,* *Agelastica alni, Haltica quercetorum* Foudr, *Melasoma aenea* L., *Melasoma populi, Galerucella luteola* Muell. Among *Meloidae* there is *Lytta vesicatoria* L. From *Cynipidae* f there are: *Diplolepis quercus-folii* L., *Andricus foecundatris* Hart. From *Diaspididae* there are: *Lepidosaphes ulmi* L., *Diaspidiotus perniciosus* Comst., *Parthenolecanium corni* Воиche.

Insects of buds and shoots of conifers. The most common species include Tortricidae family: *Rhyacionia buoliana* (Denis & Schiffermüller, 1775), *R. duplana* (Hübner, 1813), *Blastesthia turionana* (Hübner, 1813), *Retinia resinella* (Linnaeus, 1758). and *Pyralidae: Dioryctria abietella*.

Root pests are one of the most common and harmful groups of insects. They cause great damage in nurseries and for young plants.. Pests of the roots include the larvae of cockchafers, wireworms, cabbageworms, false wireworms, caterpillars of Noctiuidae, larvae of some weevils, etc. The most common and harmful among them are the larvae of cockchafers.

Cockchafers belong to the *Scarabaeidae* family. The most dangerous are *Melolontha hippocastani* F., *Melolontha melolontha* L., *Polyphylla fullo* L., *Anoxia pilosa* F., *Amphimallon solstitialis* L.

Task. Describe insects of the above ground and underground parts of the plants and fill the table 5. Do next step:

1. Provide the examples of needle- and leaf-eating insects.
2. Provide the examples of insects of buds and shoots.

3. Provide the examples of root insects.

Table 5. Insects of the above ground and underground parts of the plants

Insects	Above ground	Underground parts
Needle-eating		
Leaf-eating		
Bud and shoot pests		
Root pests		

References:

[2, 27, 28, 29, 30,32]

Questions:

1. Give the examples of needle-eating insects
2. Give the examples of leaf-eating insects.
2. Give the examples of bud and shoot insects.
3. Give the examples of root insects.

PRACTICAL WORK 5.
STEM INSECTS

The purpose of practical work. To learn stem insects.

Theoretical provisions.

Most bark beetles settle the trees in the bark, phloem or surface layer of the sapwood (fig. 4). Some species gnaw deep galleries in the wood. Bark beetles live in families: one male and several females (polygamy), or one male and one female (monogamy).

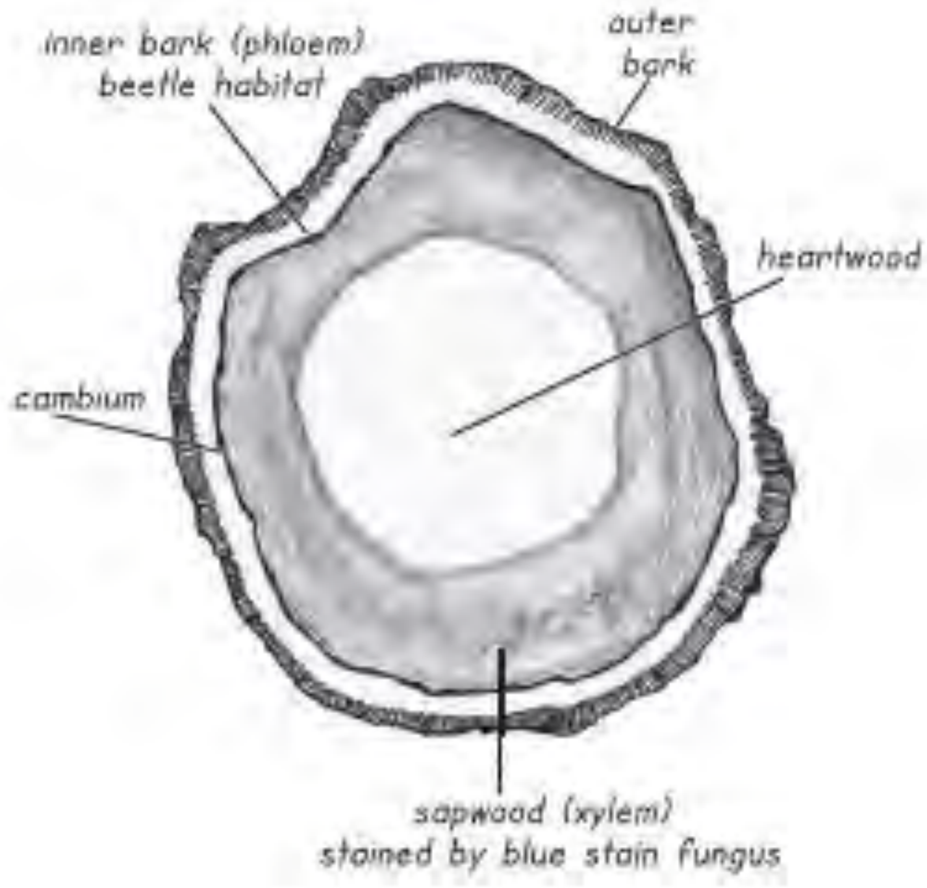

Figure 4. Woodcross-sectionn

Polygamous bark beetles first gnaw through the entrance channel, and then the nuptial chamber (fig. 5). From it, each female gnaws a separate mother gallery in the form of a straight or curved channel. On the sides of the passage, it gnaws out small recesses – egg chambers, in each of which it lays an egg. The larvae that hatch from the eggs gnaw the larval galleries. Having finished feeding, the larvae arrange pupal chambers and pupate there. Young beetles, after emerging from the pupae, gnaw through a hole in the bark and fly out.

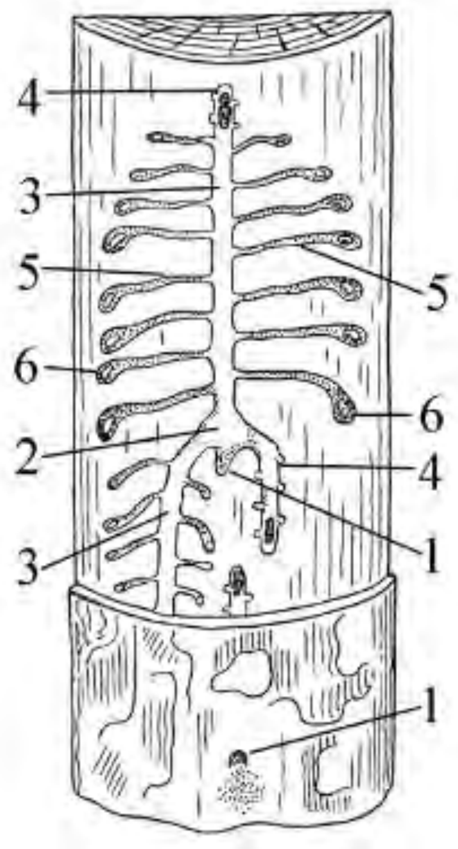

Figure 5. Bark beetle galleries

1. Entrance hole. 2. Nuptial chamber. 3. Mother gallery.

4. Egg chambers. 5. Larval galleries. 6. Larvae.

The galleries of monogamous bark beetles differ from the galleries of polygamous ones in that they do not have a nuptial chamber and have only one mother gallery.

The stem harmful insects include insects from the subfamily Scolytinae of *Curculionidae* family, as well as the families *Cerambycidae*, *Buprestidae*, *Siricidae*, *Cossidae*, *Aeqoriidae* and some others.

In most species, the larvae lay under the bark and in the wood. Larvae of bark beetles and partly adults have a hidden lifestyle under the bark and even in the wood, where, making their way, they feed and reproduce. By gnawing galleries, these pests cause significant physiological damage to trees, contributing to their death. Spring and summer phenological groups of stem pests are distinguished according to the terms of development. Insects that belong to the spring phenological group inhabit trees in April-May, and their progeny flies out at the end of June-July. Pests of the summer phenological group inhabit trees in June-August, their offspring, as a rule, remain to winter under the bark or in the wood and complete the development the following year or even later.

Bark beetles on conifers: *Tomicus piniperda* L., *Tomicus minor* Hartig, *Ips sexdentatus* Boerner, *Trypodendron lineatum* Ol., *Ips acuminatus* Qum., *Ips typographus* L., *Ips dublicatus* S., *Pityogenes chalcographus* L., *Dendroctonus micans* Kug.

Bark beetles on hardwoods: *Scolytus intricatus* Ratz., *Xyleborus dispar* Fabr., *Scolytus scolytus* F., *Scolytus ratceburgi* Jans., *Hylesinus crenatus* F., *Hylesinus fraxini* Panz., *Monochamus galloprovincialis* Ol., *Acanthocinus aedilis* L., *Spondylis buprestoides* L., *Monochamus sutor* L., *Phaenops cyanea* Fr., *Anthaxia quadripunctata* L., *Cossus cossus* L., *Zeuzera pyrina* L.

Task. Describe cycles of stem insect development and fill table 6. Do the next step:

1. Provide examples of stem insects of deciduous tree species.
2. Provide examples of stem insects of coniferous tree species.

Table 6. Stem insects of deciduous and coniferous tree species

Tree species	Stem insects

References:

[2, 27, 28, 29, 30,32]

Questions:

1. What pests of stem and branches do you know?
2. Which parts of the wood cross section do you know?
3. What damage do pests of stems and branches cause to trees?
4. Name the features of stem pests of *Lepidoptera*.
5. Name the features of stem pests of *Hymenoptera*.
6. . Name the features of stem pests of *Coleoptera*.
7. Describe a detailed life cycle of *Dendroctonus micans*.
8. Describe a detailed life cycle of *Xyleborus dispar*.
9. Describe a detailed life cycle of *Tomicus minor*.
10. Describe a detailed life cycle of *Tomicus piniperda*.
11. What parts of bark beetle gallery system do you know?
12. What difference is between polygamy and monogamy?
13. What insects hibernate in the larval stage?

PRACTICAL WORK 6
CLASSIFICATION OF DISEASES

The purpose of practical work. To learn about viral and bacterial diseases.

Theoretical provisions.

A disease is a violation of the normal metabolism of cells, organs, and the whole plant, caused by the pathogen or adverse environmental conditions that can lead to a decrease in the productivity of woody plants or to their death.

There are infectious and non-infectious diseases of woody plants. Non-infectious diseases are caused by unfavorable environmental conditions due to sharp fluctuations and violations of the regime of humidity, air and soil temperature, insufficient lighting, exposure to toxic substances, inconsistency in plant nutrition, etc..

Infectious diseases are caused by fungi (mycoses), bacteria (bacterioses), viruses (viroses), mycoplasmas, flower parasites, and nematodes. The most common (or most known) are fungal diseases of plants (mycoses).

Most plant diseases – about 85 percent – are caused by fungal or fungal-like organisms. However, other serious diseases of food and feed crops are caused by viral and bacterial organisms. Certain nematodes also cause plant diseases. Some plant diseases are classified as “abiotic”, or diseases that are non-infectious and include damage from air pollution, nutritional deficiencies or toxicities, and grow under less than optimal conditions.

Viruses and bacteria come in different shapes and sites, but bacteria are usually about 100 times bigger.

Virus *(fig. 5) is* an infectious agent of small size and simple composition that can multiply only in living cells of animals, plants, or bacteria. ***Viruses*** are intracellular (inside cells) pathogenic particles that infect living organisms. The name is from a Latin word meaning “slimy liquid” or “poison”.

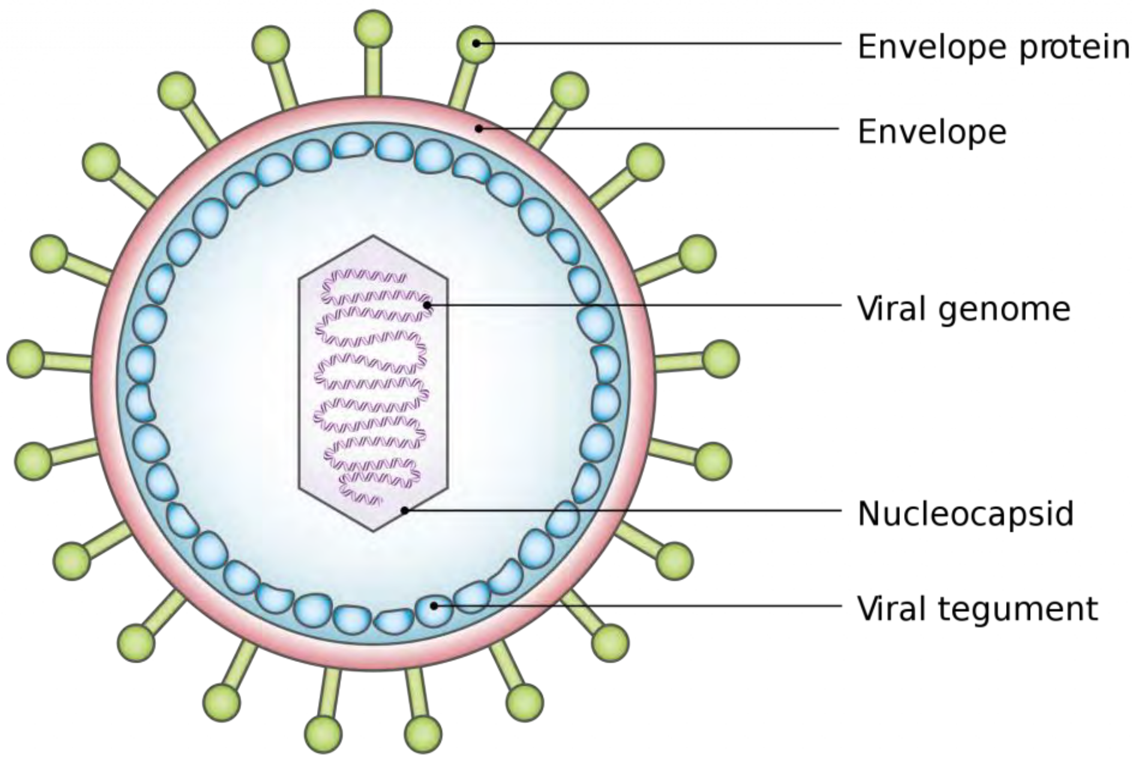

Figure 5. *Virus* cell anatomy

Bacteria *(fig. 6)* are microscopic, single-celled prokaryotic organisms, without a defined nucleus, that are reproduced asexually by binary fission (one cell splitting into two). They occur singly or in colonies of cells. Bacteria are classified into two main groups based on cell wall structure, which can be determined by a simple staining procedure called the Gram stain. Gram-negative bacteria stain red or pink and Gram-positive bacteria stain purple. The difference in colour is directly related to the chemical composition and structure of their cell walls. The cells can be rod-shaped, spherical, spiral-shaped, or filamentous. Only a few of the latter are known to cause diseases in plants. Most bacteria are motile and have whip-like flagella that propel them through the water.

Bacteria only become active and cause problems when factors are conducive for them to multiply. They are able to multiply quickly. Some factors conducive to infection include:

- high humidity;
- crowding; poor air circulation;
- plant stress caused by over-watering, under-watering, or irregular watering;
- poor soil health;
- deficient or excess nutrients.

The biggest difference between bacteria and viruses is that bacteria are considered living beings and are cells, whereas viruses are not (and are not cells).

Bacteria are unicellular organisms. They are ubiquitous on Earth.

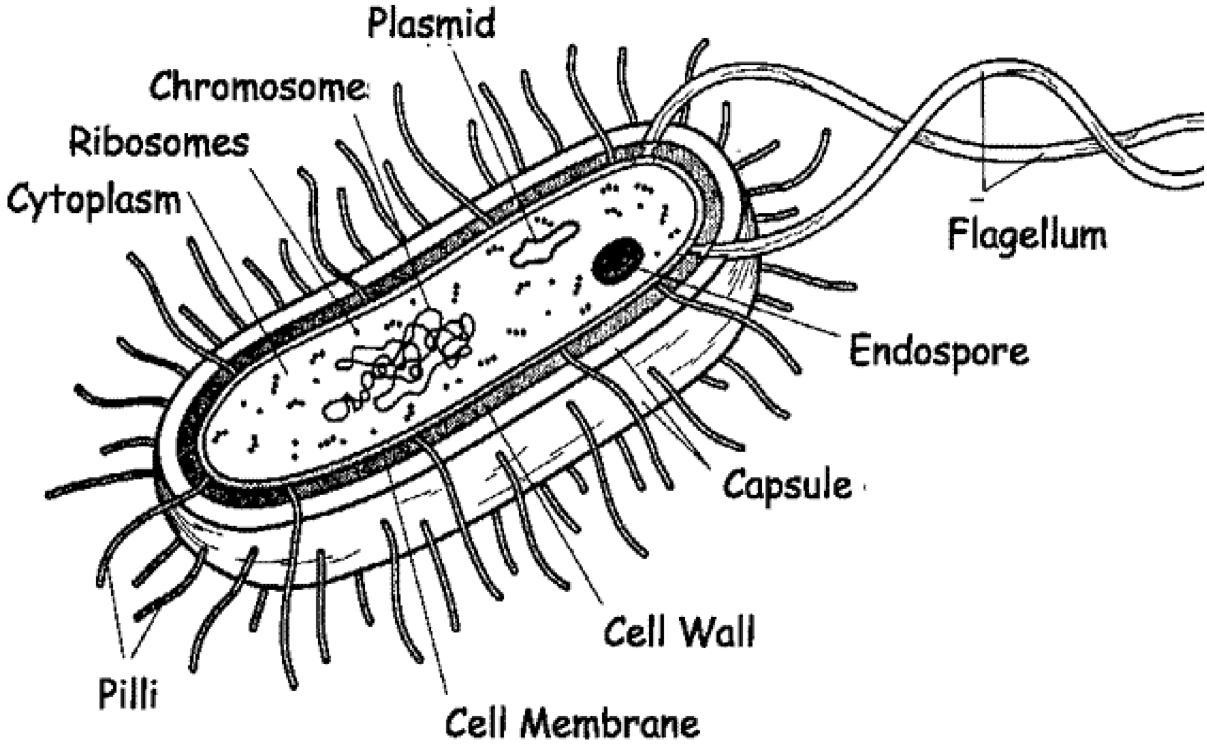

Figure 6. Bacteria cell anatomy

Viruses are not incluses into organism classification scheme, as they are not considered living beings. They have not cells like organisms; instead, they are generally composed of a protein coat surrounding genetic material – deoxyribonucleic acid (DNA) or ribonucleic acid (RNA).

Viruses are generally parasitic in some way. Most tend to damage their hosts. Some bacteria do this, but many do not.

Bacteria are reproduced by binary fission, while viruses must use host cells to create more viruses.

Viruses sometimes even attack bacteria.

The most common are the following consequences of diseases:

- dying of a plant or its individual parts, wilting.

- complete or partial destruction of individual parts of plant (spots, ulcers, pustules, frostbite cracks, rots,).

- accumulation of fungal mycelium and spores (mummification).

- change in the shape of plant parts (deformation, curliness, curvature of branches, fasciation).

- change in color of plant parts (mosaic, chlorosis).

- neoplasms on the affected organs of plants ("witches brooms", growths, tumors).

- discharge in places of damage and damage to plants (gum and resin discharge).

Task. Describe types of bacterial diseases and fill the table 4. Do the next step:

1. Describe different types of diseases.
2. Describe signs and symptoms of bacterial disease.
3. Describe viral disease symptoms.
4. Provide examples and describe 5 types of bacterial diseases.
5. Provide examples and describe 5 types of viral diseases.

Table 4. Bacterial and viral diseases

Diseases	Species
Bacterial	1. 2. 3. 4. 5.
Viral	1. 2. 3. 4. 5.

References:

[10, 26, 34, 35]

Questions:

1. Define the term "plant disease".
2. What is the difference between "types" and "symptoms" of woody plant diseases?
3. List the groups of types of diseases and give their main characteristics.

4. What is the prevalence, harmfulness and harm of diseases of woody plants? Explain these concepts by a concrete example.
5. Explain the essence and importance of diagnosing plant diseases.
6. Give some examples of morphological changes in a diseased plant.
7. What do you know about teratological phenomena in woody plants?
8. Give specific examples of infectious and non-infectious diseases.
9. List and describe the main causes of non-infective diseases.
10. What are the features of the control the non-communicable forest diseases?

PRACTICAL WORK 7
CLASSIFICATION OF FUNGI

The purpose of practical work. To learn different types of fungi.

Theoretical provisions.

The term fungus was directly adopted from the Latin word “fungus”. The scientific study of fungi is believed to have originated in 1836 with Miles Joseph Berkeley's publication. Earlier, taxonomists contemplated that fungi were closely related to plants, based on their similar morphology and growth habitat. Later, it was realized that fungi were a separate kingdom. Around 144,000 species of fungi have so far been formally described. But it can be 2,2–3,8 million species and therefore, the actual number is far from it was described.

Traditionally, fungal species have been distinguished by different approaches and concepts based on morphology, physiology, biochemistry or reactions to chemical tests. Classification based on phenotypic characters is the most common traditional method used in defining fungi.

Most of the organelles present in fungal cells are similar to those of other eukaryotes. Fungal nuclei are usually small (< 2 μm diameter). Fungi have been found to possess between 6 and 21 chromosomes. Many fungi (*Ascomycota*) have a life cycle that is predominantly haploid, while others (*Basidiomycota*) have a long dikaryotic phase.

Chytridiomycota is the simplest and most primitive *Eumycota*, or true fungi. They produce gametes and diploid zoospores that swim with the help of a single flagellum.

The ecological habitat and cell structure of chytrids have much in common with protists. Chytrids usually live in aquatic environments, although some species live on land. Some species thrive as parasites on plants, insects, or amphibians, while others are saprobes.

The zygomycetes are a relatively small group of fungi belonging to the phylum *Zygomycota*. They include the familiar bread mold, which rapidly propagates on the surfaces of breads, fruits, and vegetables. Most species are saprobes, living off decaying organic material; a few are parasites, particularly of insects.

The majority of known fungi belong to the phylum ***Ascomycota***, which is characterized by the formation of an **ascus** (plural, asci), a sac-like structure that contains haploid ascospores.

Many ascomycetes are of commercial importance. Some play a beneficial role, such as the yeasts used in baking, brewing, and wine fermentation. Other ascomycetes parasitize plants and animals, including humans.

The fungi in the phylum ***Basidiomycota*** are easily recognizable under a light microscope by their club-shaped fruiting bodies called **basidia** (singular, basidium), which are the swollen terminal cells of a hypha. The basidia, which are the reproductive organs of these fungi, are often contained within the familiar mushrooms, commonly seen in fields after rain. These mushroom-producing basidiomyces are sometimes referred to as "gill fungi" because of the presence of gill-like structures on the underside of the cap. The "gills" are actually compacted hyphae on which the basidia are borne. This group also includes shelf fungus, which clings to the bark of trees like small shelves. In addition, the basidiomycota includes smuts and rusts, which are important plant pathogens; toadstools, and shelf fungi stacked on tree trunks. Most edible fungi belong to the phylum *Basidiomycota.*

Imperfect fungi are those that do not display a sexual phase. They are classified in the phylum *Deuteromycota*.

They form visible mycelia with a fuzzy appearance and are commonly known as **molds**.

Task. Describe different types of fungi. Fill the table 4. Do next steps:

1. Provide examples and describe 5 species of *Chytridiomycota*.

2. Provide examples and describe 5 species of *Zygomycota*.

3. Provide examples and describe 5 species of ***Ascomycota***.

4. Provide examples and describe 5 species of ***Basidiomycota***.

5. Provide examples and describe 5 species of *Deuteromycota*.

6. Sign the main parts of a fungus (fig. 7).

Table 4. Species of fungi

Phylum	Species
Chytridiomycota	1. 2. 3. 4. 5.
Zygomycota	1. 2. 3. 4. 5.
Ascomycota	1. 2. 3. 4. 5.
Basidiomycota	1. 2. 3. 4. 5.
Deuteromycota	1. 2. 3. 4. 5.

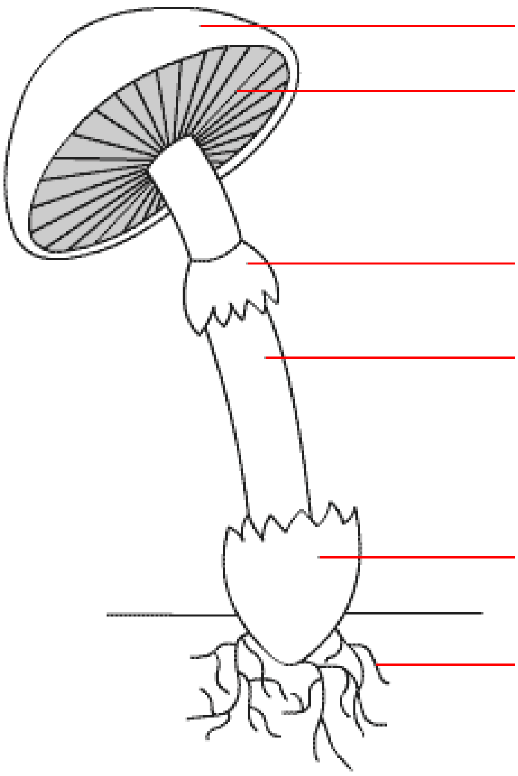

Figure 7. Parts of a fungus

References:

[10, 26, 34, 35]

Questions:

1. What is the importance of fungi in forest ecosystems?
2. What characteristic is the cause that places fungi in a different kingdom?
3. When was the first scientific study of fungi originated?
4. How fungi are divided according to the method of nutrition?
5. How many species of fungi have so far been formally described?
6. How many actual fungi species exist in the world?

7. How many chromosomes have been found in fungi?
8. Describe a life cycle of different phyla of fungi.
9. Describe fungal reproduction.
10. What phyla of fungi are common in the forests?
11. What part of fungus do you know?
12. What fungi cause stem rot?
13. What fungi cause root rot?

PRACTICAL WORK 8
SPREAD OF WOODY PLANT ROTS

The purpose of practical work. To learn rots of woody plants.

Theoretical provisions.

Rots are caused by some species of fungi. Rot diseases are characterized by plant decomposition and putrefaction. The decay may be hard, dry, spongy, watery, mushy, or slimy and may affect any plant part.

Diseases that infect underground plant parts are prevalent on both herbaceous and woody ornamental plants. They can be caused by fungi, bacteria or soil-borne nematodes. Infections that lead to disintegration of underground tissues are difficult to manage because they are not visible. The symptoms are thus typically expressed late in the stage of extensive infestation when disease has progressed beyond control. Lastly, management is difficult because soil treatments are ineffective. Some of the more severe pathogens are those that can persist for long periods without a living host. These survive in a dormant state or as resistant structures capable of surviving in the environment until they meet their next susceptible host.

Rhizoctonia and *Phytophthora* are fungi rots. These two fungi can attack the root systems of many different plants. *Rhizoctonia* prefers drier soil conditions, but in the greenhouse it can produce an aerial web blight that infects foliage under high humidity. Below ground, *Rhizoctonia* may infect roots and stems and produce reddish cankers. *Phytophthora* is a water mold fungus that can be active in conditions of free moisture or of flooding. Both fungi can produce damping-off disease, a name given to conditions where tender seedlings die from root and stem soil line infections. Bulb rots occur on plants with underground storage organs. Because these organs are often sites for storage reserves and are high in carbohydrates, they are especially susceptible to underground rots. Often the initiation of a bulb rot is due to a wound created by an insect or by mechanical means. This opportunity lowers the plant's defence and allows for colonization by bacteria or fungi.

Bacteria can enter the host tissue only through wounds, but bacterial soft rots can be very destructive. These may originate in the leaves where bacteria enter and migrate to the bulb or rhizome or directly at the storage organ. Often a foul smell accompanies a bacterial soft rot infection.

Crown and collar rots occur at the soil line where the plant emerges. In this zone, the plants must be able to withstand the freeze-and-thaw cycle as well as the mechanical abrasion of soil particles. When wounds are produced, fungi and bacteria can invade the host tissue. A crown rot is typically associated with herbaceous plants. The tissue may turn brown to black in the localized area around the soil line. The discoloration may migrate upward and downward around the outside of the tissue from the point of infection. Eventually, when the pathogen has almost completely encircled the stem, the plant will begin to show wilting and dieback symptoms. Collar rots are typically associated with the woody stems of trees and shrubs at the soil line. Poorly drained soils and nutrient deficient soils can lead to plants being more susceptible to collar rots. As the pathogen enters a host tissue at the soil line, it may grow down into the roots where it can cause extensive damage. Control of these types of diseases is very difficult.

Phellinus pini is a fungal plant pathogen that causes tree disease commonly known as "red ring rot" or "white speck". This disease extremely common in the conifers, decays tree trunks, rendering them useless for lumber. *Phellinus pini* most often affects Scots pine, but it can develop on larch, yew, fir, pseudotsuga, cedar. It is a rot of the heartwood. Signs of the fungus include shelf-shaped fruiting bodies protruding from the trunks of trees. Spores produced on fruiting bodies are blown by the wind and go on to infect other trees. Fruiting bodies are found at a height of up to 8 meters.

Fomitopsis pinicola is a stem decay fungus common on softwood and hardwood trees. The species is common throughout temperate Europe and Asia. It causes yellowish-brown core and sapwood trunk rot. It occurs on dead or severely weakened trunks of spruce and other conifers, as well as on deciduous tree species. Growing trees become infected with basidiospores due to mechanical damage, even minor.

Phaeolus schweinitzii causes butt rot on conifers such as Douglas-fir, spruce, fir, hemlock, pine, and larch. It is native to North America and Eurasia. The fruiting bodies appear in late summer or fall. They are yellow with darker brown centres, with orange to pale margins on young specimens. They may grow beyond 25 cm in diameter. As the fruiting bodies age, the pore surface turns from yellow to greenish yellow, the top becomes darker, and the yellow-brown flesh becomes harder and more wood-like. The pores bruise brown. The spores are white, elliptical, smooth. This fungus causes brown rot, which degrades the cellulose. Infection with the causative agent of rot occurs through the roots and mycelium when in contact with diseased trees. From diseased roots, the rot passes into the trunk and rises along it to a height of 2 m.

Fomes fomentarius is a species of fungal plant pathogen found in Europe, Asia, Africa and North America. The species produces very large polypore fruit bodies which are shaped like a horse's hoof and vary in colour from a silvery grey to almost black, though they are normally brown. It grows on the side of various tree species , which it infects through broken bark, causing rot. The species typically continues to live on trees long after they have died, changing from a parasite to a decomposer. It suppresses the white "marble" core and sapwood stem rot. The fungus affects the trunks of beech, ash, birch, aspen, poplar, willow, hornbeam, alder, cherry, maple and many other deciduous species. Trees are infected with basidiospores due to frost cracks, mechanical damage to the trunk and places of broken bough.

Laetiporus sulphureus is a species of bracket fungus found in Europe and North America. Its fruit bodies grow as striking golden-yellow shelf-like structures on tree trunks and branches. Old fruitbodies fade to pale beige or pale grey. The undersurface of the fruit body is made up of tubelike pores. Fruit bodies are annual, flat, collected in groups. *Laetiporus sulphureus* is a saprophyte and occasionally a weak parasite, causing brown cubical rot in the heartwood of trees on which it grows. This fungus is found on the trunks of oak, ash, beech, willow, acacia, maple, cherry, walnut, larch, fir, spruce, cedar and other woody plants.

Phellinus igniarius lives by saprotrophic nutrition, in which the lignin and cellulose of a host tree is degraded and is a cause of white rot. The fungus forms perennial fruiting bodies that grow as woody-hard, hoof or disc-shaped brackets from the bark of the infested living tree or dead log. The tree species is often willow but it may be commonly found on birch, aspen, hornbeam and alder and other broad leafed trees. Unlike most fungi it has a hard woody consistency and may persist for many years, building a new surface layer each year. At first, the affected wood turns brown, and then acquires a yellow-white color. The fungus causes central rot of trunks and thick branches.

Daedalea quercina is found in Europe, Asia, Northern Africa and Australasia. This fungus causes dark brown core-synchymal stem rot of oak. The fungus affects old trunks of common oak with mechanical damage, but it is most often found on stumps and felled processed wood of oak, chestnut, alder and beech. Trees are infected with basidiospores through wounds and broken branches.

Fomitopsis betulina is a common bracket fungus and grows almost exclusively on birch trees. The brackets grow on the bark of the tree, and these fruit bodies can last for more than a year. The fungus causes red-brown core and sap rot of birch. The fungus is widespread and affects only birch trunks. First, the core part of the trunk is destroyed, then the sapwood.

Armillaria mellea is a plant pathogen. It causes white sapwood or root rot of coniferous and deciduous tree species. The symptoms of infection appear in the crowns of infected trees as discoloured foliage, reduced growth, dieback of the branches and death. It is found on more than 200 species of woody and shrubby plants in all parts of the world. The mushrooms are edible. *Armillaria mellea* grows typically on hardwoods but may be found around and on other living and dead wood or in open areas.

Heterobasidion annosum causes one of the most destructive diseases of conifers. The disease caused by the fungus is named root rot. Also *Heterobasidion annosum* leads core or core-sapwood rot of conifers. The fungus affects Scots pine, spruce, larch, Weymouth pine, and fir. It is occasionally found on some soft-leaved tree species of plants, for example, on the bank, aspen, aspen.

Agrobacterium radiobacter is the causal agent of crown gall disease (the formation of tumours) in over 140 plant species. It is a rod-shaped soil bacterium. The pathogen affects apple, pear, plum, cherry and some other tree species. Infection of the roots occurs in the soil when they are damaged by rodents and insects, as well as during transplanting when the roots are cut with non-disinfected tools. When affected by the causative agent, wounds and tumors of various sizes appear on the roots, which are formed as a result of the growth of parenchymal tissue of the secondary cortex. Over time, the tumors become woody.

Tasks. Describe root and stem rots of woody plants. Do the next steps:

1. Give the classification of woody plant rots by etiology, color, location and structure.
2. Get acquainted in detail with the causative agents of root rot, give the main signs of their manifestation and prognosis.
3. Get acquainted in detail with the causative agents of stem rot, give the main signs of their manifestation and prognosis.

References:

[10, 26, 34, 35]

Questions:

1. What plant parts can be affected by fungi or bacterial rots?
2. Give a brief description of *Phellinus pini.*
3. Give a brief description of *Fomitopsis pinicola* and *betulina.*

4. Give a brief description of *Phaeolus schweinitzii.*
5. Give a brief description of *Fomes fomentarius.*
6. Give a brief description of *Laetiporus sulphureus.*
7. Give a brief description of *Phellinus igniarius.*
8. Give a brief description of *Daedalea quercina.*
9. Give a brief description of *Armillaria mellea.*
10. Give a brief description of *Agrobacterium radiobacter.*
11. Give a brief description of *Heterobasidion annosum.*

PRACTICAL WORK 9
CLASSIFICATION OF WEEDS

The purpose of practical work. To learn the classification of weeds.

Theoretical provisions.

Thanks to wide inter-row spaces and open canopy in the early phases of establishment, forest nurseries and plantations represent ideal places of floristically rich and diverse weed flora. Weeds have an exceptional capacity of adaptation to environmental conditions because most produce vast quantities of seeds, which enable great expansion.

Although the geographic weed distribution and compositiondepends mainly on climate factors, the vegetation within each climate region is differentiated under the effect of edaphic factors. The soil physical and chemical properties, as well as climate conditions, have primary significance for both cultivated plants and weeds.

However, all weeds do not have equal significance. When considering weed control attributes, perennial weeds are a far greater challenge due to difficulties employing mechanical means, because perennials are often stimulated to grow and disperse even more intensively.

The problem of forestry weeds came to the fore in recent years as more and more attention has been paid to establishing and restoring forests. In afforested areas, luxuriate development of weed vegetation can imperil the survival and development of seedlings. The harmful effect of weeds is reflected in the worsening of basic living conditions such as humidity, light, and nutrients, poor seed germination, and seedlings' growth. Compared to cultivated plants, weedy plants show considerable plasticity in relation to numerous ecological factors. One of the most important weed traits is the expressed adaptation ability. Another important weed trait is the pronounced resistance to unfavourable environmental conditions (drought, moisture, wind etc.). Many weeds are resistant to plant diseases and pests. In addition, one of the weed traits is the periodicity of germination. Very often weed seeds do not germinate at once, but rather in different time periods, and it is hard to control weeds simultaneously. In addition, many weeds produce an enormous quantity of seed, which makes it easier for them to spread and expand in space.

Many invasive weed species are exotic, but many native species also proliferate when given disturbed soils and protected environments. Once such weeds are introduced, they are very costly to eradicate and can inflict serious harm on forest sites.

Annual weeds live only for a season or a year and complete their life cycle in that season or year. These are small herbs with shallow roots and weak stems. This weed produces seeds in profusion and propagates commonly through seeds. After seeding the annuals die away and the seeds germinate and start the next generation in the next season or year following. The most common field weeds are annuals.

Biennials weeds complete the vegetative growth in the first season, flower and set seeds in the succeeding season, and then die. These weeds are found mainly in non-cropped areas.

Perennials live for more than two years and may live almost indefinitely. They adapted to withstand adverse conditions. They propagate not only through seeds but also by underground stem, roots, rhizomes, tubers, etc.

An ***invasive species*** can be any kind of living organism – an amphibian (like the cane toad), plant, insect, fish, fungus, bacteria, or even an organism’s seeds or eggs – that is not native to an ecosystem and causes harm. They can harm the environment, the economy, or even human health. Species that grow and reproduce quickly, and spread aggressively, with the potential to cause harm, are given the label “invasive”.

There are numerous measures and procedures for weed control in forestry today, but in order to control weeds successfully, they should consist of different care and control measures.

There are six classifications of weed control measures: preventive, mechanical, physical, mulching, biological weed control, herbicides.

The Law of Ukraine on plant quarantine determines the general legal, organizational, financial and economic basis of plant quarantine, activities of the state bodies, enterprises, institutions, organizations, officials, and citizens aimed at preventing the entry and spreading of dangerous pests, plant diseases and weeds which are not present in the territory of Ukraine.

Tasks. Describe classification of weeds and invasive species. Fill the tables 5 and 6. Do the next steps:

1. Provide examples and describe 5 species of annual weeds, biennials, perennials (shallow rooted perennials, deep rooted perennials).

4. Provide examples and describe 5 invasive species.

5. Describe the effectiveness of treatments.

Table 6. Effectiveness of weed treatments

Treatment alternatives	Plants				Potential environmental impacts
	Annual	Biennials	Perennial	Wood species	
Herbicides					
Cutting					
Cultivation					
Mulching					

Table 5. Species of weeds or invasive plants

Plants	Species
Annual weeds	1. 2. 3. 4. 5.
Biennials weeds	1. 2. 3. 4. 5.
Perennial weeds	1. 2. 3. 4. 5.
Invasive species	1. 2. 3. 4. 5.

References:

[6, 14, 16, 17, 24]

Questions:

1. What is the concept of weeds in forestry?
2. Describe the properties of weed species.
3. List and describe highly invasive plant species of Ukraine.
4. Describe the foundation of weed control in forestry.
5. What are the alternatives of weed treatment?

6. How to use pesticides to control weeds?
7. Explain the negative impact of chemical care and application of pesticides on the forest.
8. List the features of annual, biennials, perennials weeds.
9. Provide a brief description of the Law of Ukraine on plant quarantine.
10. Give the definition of plant quarantine, special quarantine regime and quarantine objects.
11. What type of weed treatments do you know?
12. What is the effectiveness of weed treatments?
13. What are potential environmental impacts due to different weed treatment alternatives?
14. Give examples of herbicides.
15. What is mulching?
16. What differences are between annual and perennial weeds?

PRACTICAL WORK 10

INSECTS AND DESEASES OF THE MAIN TREE SPECIES

The purpose of practical work. To learn insects and diseases of the main tree species

Theoretical provisions.

The forests of Ukraine are formed by more than 30 tree species, among which *Pinus silvestris*, *Quercus robur*, *Fagus silvatica*, *Picea abies*, *Betula pendula*, *Alnus glutinosa*, *Fraxinus excelsior*, *Carpinus betulus*, *Abies alba* are the dominants.

Young plants grown in nurseries are very sensitive to adverse external conditions and susceptible to infectious diseases. Minor damage can lead to drying out or damage by pathogens. Pathogens of seedlings affect roots, stems, cotyledons, needles, and leaves.

Diseases of needles and leaves are common in nurseries, plantings of green zones, protective and decorative plantings. They are diverse in character and origin. Diseases of needles and leaves are caused by fungi, bacteria, viruses and non-parasitic factors. The most common diseases are shutte, powdery mildew, spotting, leaf deformation, etc. These diseases are especially dangerous for young plants and often lead to their death. With mild damage, seedlings or young plants weaken, reduce growth, which often contributes to the development of even more dangerous diseases.

In mature plants, the harmfulness of diseases of leaves or needles is less; have little effect on growth, but create a constant threat of accumulation of infection to damage young plants in nurseries. The disease of the leaves is especially widespread after damage to plants by phytophagous insects or due to adverse climatic factors.

Diseases of branches and stems are very diverse. They affect trees and shrubs of different ages - from young seedlings to old trees, among them necrotic and vascular diseases are very common.

Task. Describe possible insects and diseases of the main tree species and fill the table 8. Do next step:

1. Brief description of the main tree species.

2. Characteristics of insects with the cycles of their seasonal development.

2.1. What part of the tree is affected?

2.2. The main control measures .

3. Characteristics of diseases (viral, bacterial, fungal) with the cycles of their seasonal development.

3.1. What part of the tree is affected?

3.2. The main control measures .

References:

[6, 17, 26–35]

Questions:

1. Give examples of the most common pests of *Quercus robur*.
2. What parts of *Quercus robur* are affected?
3. Give examples of the most common pests of *Pinus sylvestris* 4. What parts of *Pinus sylvestris* are affected?
5. Give examples of the most common pests of *Betula pendula*
6. What parts of *Betula pendula* are affected?
7. Give examples of the most common pests of *Acer platanoides*
8. What parts of *Acer platanoides* are affected?
9. Give examples of the most common pests of *Aesculus hippocastanum*
10. What are the consequences of the activities of *Quercus robur* pests?
11. What are the consequences of the activities of *Pinus sylvestris* pests?
12. What are the consequences of the activities of *Betula pendula* pests?
13. What are the consequences of the activities of *Acer platanoides* pests?
14. What are the consequences of the activities of *Aesculus hippocastanum* pests?

Table 8. Insects and diseases that parasitize and destroy the main tree species in East Europe

Parts of tree	Insects	Nematodes	Diseases	Rot	Fungi
***Quercus robur* L.**					
Reproductive plant part					
Fruit					
Leaves					
Bark					
Bast wood					
Root					
***Pinus sylvestris* L.**					
Reproductive plant part					
Fruit					
Needles					
Bark					
Bast wood					
Root					
***Betula pendula Roth*.**					
Reproductive plant part					
Fruit					
Leaves					
Bark					
Bast wood					
Root					

Acer platanoides L.					
Reproductive plant part					
Fruit					
Leaves					
Bark					
Bast wood					
Root					
Aesculus hippocastanum L.					
Reproductive plant part					
Fruit					
Leaves					
Bark					
Bast wood					
Root					

INDIVIDUAL WORK 1
METHODS OF INTEGRATED PEST MANAGEMENT

The purpose of practical work. To study methods of Integrated Pest Management

Integrated Pest Management (IPM) is an environmentally friendly and cost effective approach that utilizes a variety of preventative measures, cultural controls, and direct control measures to promote plant health. No single activity in an IPM program is effective on its own; rather, all of the components of the program contribute to plant health and when used together, effectively keep pest problems below a tolerable threshold. The first and most important step in establishing and maintaining a healthy forest is proper forest management. Planting the appropriate tree species for the site, managing competing vegetation, maintaining appropriate stocking, minimizing injury and stress, and adhering to sound silvicultural methods is the first step in preventing disease and insect problems, and minimizing the impacts of stress agents. In urban forests, proper tree care including water, fertilization, pruning, mulching, and correct species selection will promote long-lived trees that provide many benefits. An important component of proper forest management and tree care is monitoring the health of the forest and trees within it. Because of the difficulties encountered when managing forest health problems (as discussed above), it is best to detect and mitigate problems early and when they occur at small, localized levels. When an outbreak or epidemic occurs, foresters are often left with very few effective control options. An awareness of the health of your forest, the health of trees in the surrounding area, past predisposing factors, and any changes in the forest community that could throw the natural cycle out of balance is critical to prevent widespread and severe damage by pests. Foresters have a variety of methods at their disposal to prevent, manage, and control pest problems.

The following approaches can all be used as a part of an integrated pest management program:

1) Exclusion, otherwise known as quarantine, targets the introduction of forest pests. Quarantines may be difficult to establish but are usually the cheapest method of pest control. Quarantines are only effective when the pest is not already present in an area, and when natural or artificial boundaries can be established that can effectively prevent introductions. Internal quarantines are utilized to keep a pest inside of the area where the pest is already established. Laws and regulations forbid the export of potentially infested material out of the quarantine zone without certification. External quarantines are enacted in areas free of a certain pest and prevent the importation of potentially infested materials into the pest-free zone. Quarantines can be enacted at city, state, regional, and international levels, but can also be utilized on much smaller scales. For instance, growers can inspect seedlings at the time of planting for disease or insect problems carried in on nursery stock, and effectively exclude those pests

from becoming introduced into the stand. The use of soil-less planting media in containerized nursery stock may prevent the introduction of soil-borne pathogens, and the use of only local seeds and plant materials can avoid the establishment of non-native pests.

2) Eradication is utilized when a quarantine has failed. The ultimate goal of eradication is to completely eliminate the pest from an area so that an external quarantine can be established. But complete eradication is only possible when pest populations are small, or when the pest is highly sensitive to control measures. In forestry, this is rarely the case, so eradication is also referred to as sanitation. Sanitation seeks to reduce the pest population below acceptable levels but usually does not result in the complete elimination of the pest. Sanitation and eradication can be achieved through fumigation, crop rotation, destruction of infested/infected plants or plant parts, and destruction of potential hosts.

3) Protection is utilized to protect susceptible plants from attack, injury, or disease when a pest is present. Also known as prophylactic treatments, protective measures must be in place before the tree is attacked by the pathogen or insect. Typically, prophylactic treatments consist of a protectant pesticide that is sprayed onto the surface of the plant to prevent an infestation/infection from occurring. Protectant pesticides, because they reside on the plant surface, tend to wash off over time and must therefore be applied periodically while the pest is present. However, some protectant pesticides have systemic properties that

allow the chemical to be taken up into the plants' vascular system where it may provide long-lasting protection. Protectant pesticides tend to be very effective, but are also among the most expensive control measures because of the need to constantly apply them, and the most likely to cause environmental damage or harm to non-target organisms. Because protectant pesticides need to be applied often and in large quantities, there is also an increased risk that the pest population will develop resistance to the chemical.

4) Cures, or therapeutic treatments, are available in certain cases that limit the damage to a tree that has become infected/infested by a pest, and may potentially eradicate that pest from the plant so further damage does not result. Cures cannot heal the tree, but they may allow recovery if the pest population is incapacitated, reduced, or eliminated. Therapeutic treatments usually come in the form of systemic pesticides that are injected into or taken up by the plant; translocation of the pesticide throughout the infested/infected plant is necessary for adequate control. The benefit of cures is that they can be applied only when needed (after the plant has been attacked), as opposed to prophylactic measures which must be continually applied to prevent an attack from occurring in the first place. This makes them more environmentally friendly, potentially more cost effective (over the long term), and reduces the risk of resistance development in the pest population. However, there are relatively few therapeutic options available in forestry, and they tend to be reserved for high-

value trees (landscape trees and ornamentals) because of their high cost per plant.

5) Incomplete Resistance, also known as horizontal resistance or polygenic resistance, is a type of resistance that does not prevent infection/infestation from occurring but limits the number of attacks or the extent of damage that occurs to the host. Trees with incomplete resistance may not be attacked by beetles as frequently as highly susceptible tree species, may have fewer infections by pathogens, or may have less severe symptoms/signs resulting from those attacks. Incomplete resistance is controlled by many plant genes; each gene partially contributes to plant defense, but alone they provide little protection. Overall, incomplete resistance is the best possible control option available if it is sufficient to keep damage below acceptable thresholds. The protection it provides is inexpensive, long-lasting, and durable. However, it does permit some damage to occur, and it is difficult to develop this type of resistance. Because many genes are involved, it can take many years (or generations) of plant breeding to achieve desirable results.

6) Complete resistance, also known as vertical resistance or monogenic resistance, is a type of resistance that either prevents infection/infestation completely or prevents any damage from occurring after an attack occurs. Complete resistance is controlled by a single plant gene that confers 100 percent protection to the plant from a specific pest. Obviously this type of resistance is highly desirable, and can actually be developed quickly through genetic

engineering. Occasionally, completely resistant individuals can be found in nature, and used to develop resistant plant varieties. However, initial development of a completely resistant plant variety can be very expensive. In addition, because complete resistance is only controlled by one gene, there is an increased risk that the pest population will evolve mechanisms to overcome that resistance, in which case the variety would become completely susceptible.

7) Avoidance is perhaps the cheapest and most effective option available to control pest problems, but there are few applications of avoidance available in forestry. The key to avoidance is to make the host unavailable or the environment unsuitable for pest attacks. For instance, plants can be planted earlier/later in the growing season to avoid the time of year when spores from a pathogen are produced. But because trees are long-lived organisms, this type of avoidance is difficult to achieve in forestry. However, examples of avoidance include planting trees in microclimates where the environment is not suitable for infections to occur or delayed planting of seedlings to allow pest populations to dissipate from a stand.

Tasks: Describe the damages caused by insects and pathogens, fill the table (supplement J and K). Implement recommendations for

1. Chemical pest control in the forest.
2. Cultural pest control in the forest.
3. Biological pest control in the forest.
4. Physical (mechanical) pest control in the forest.

References:

[1, 3, 5, 12, 15, 17, 18, 20]

Questions:

1. What are the main measures of integrated pest management?
2. Define ways of cultural pest control.
3. Define ways of mechanical method of IPM.
4. Define ways of chemical method of IPM.
5. Define ways of biological method of IPM.
6. Describe managing pasts with healthy soils.
7. Give a foundation of integrated pest management.
8. What do you reckom, what is better to plant: mixed or pure forest?
9. Forest pathological survey for stem pests.
10. Forest pathological inspection for coniferous and leaf-eating pests.

11. Where borers are most likely enter a tree?
12. Describe beneficial insects in the forest.
13. What birds and bats do you know for pest suppression?
14. List plants that attract beneficial insects.
15. What rules of introducing beneficial insects do you know?
16. How to control pests due to bats?
17. How to control pests due to birds?
18. How to attract insect predators?

INDIVIDUAL WORK 2. THE CROWN CANOPY CLASSES, LEAF DEFOLIATION AND DISCOLORATION

The purpose of practical work. To evaluate the crown condition.

Climate and weather fluctuations and changes are the most important environmental drivers of tree canopy defoliation, an indicator of forest health.

The crown canopy classes (after Kraft) are used as a criterion for selecting the trees, but only if the trees lack significant mechanical injuries. Social status is a measure of the height of a tree relative to the surrounding trees. Information on social status is useful as an aid to interpreting crown condition and increment data for the individual trees. Five classes of social status are recognized:

– dominant, including free-standing trees with upper crown above the general level of the canopy;

– codominant, which includes trees with crowns forming the general upper level of the canopy;

– subdominant, which includes trees extending into the canopy and receiving some light from above, but shorter than the dominant and codominant classes;

– suppressed, including trees with crowns below the general level of the canopy, receiving little direct light from above;

– dying trees.

Suppressed trees should not be equated with dying trees as, in a mixed-age stand, they represent potential future generations of trees.

In order to evaluate the condition of the crown, the needle/leaf losses are allocated to one of the five damage classes. These classes are "0" (0–10 % defoliation), "1" (10–25 % defoliation) and so on. A tree with more than 60 % and up to 100 % defoliation, which is still alive, is coded as "3". The code "4" is reserved for dead trees.

The second important damage characteristic is foliar discolouration, i.e. in most cases, a yellowing of the needles or leaves. The percentage of discoloured needles is estimated in one of five classes.

The needle (leaf) loss classes and discolouration classes are plotted against each other to determine the final damage classes.

Tasks. Give the examples of defoliation and discoloration classes, and fill the table 9. Do next step:

1. Evaluate trees by Kraft classes. Show the crown canopy classes on the examples.
2. Study of defoliation classes. Establishing the dependence of the presence of pests and defoliation classes. Show the examples of defoliation classes.
3. Study of discoloration classes. Establishing the dependence of the presence of pests and discoloration classes. Show examples of discoloration classes.

Table 8. Examples of defoliation and discoloration classes

Classes	Definition, %	Defoliation (foto)	Discoloration (foto)
0	0–1		
1	2–25		
2	26–60		
3	61–99		
4	100		

References:

[11, 13, 16, 19, 25]

Questions:

1. List and describe the crown canopy classes by Kraft.
2. How do you understand the terms "defoliation" and "Leaf discoloration"?
3. Describe the stages of "defoliation".
4. Describe the stages of "Leaf discoloration".
5. Describe the final damage classes for foliage (needle/leaf).

MAIN USED TERMS

Abdomen – the abdomen is the posterior section of the body (insect body comprised of head, thorax, and abdomen) and encloses the gut and reproductive organs.

Abiotic – pertaining to the non-living.

Acervulus – a small subcuticular or subepidermal cushionlike asexual fruiting body, without a covering of fungus tissue, producing conidia in a moist mass that escapes through a break in the host tissue.

Aeciospore – one of several kinds of spores produced by a rust fungus. Formed in and released from a fruiting structure called an aecium.

Afforestation – a set of measures to establish a forest on land, which has not been registered as a forest in the National Immovable Property Cadastre Information System.

Alternate host – another host plant species required to complete the development of an insect or pathogen.

Analysis of risks – a process of appraisal of biological, ecological and economic data for the purpose of defining the necessity of controlling the regulation of harmful organisms and necessary phytosanitary measures.

Anthracnose – a type of plant disease which typically is a leaf and twig blight. Common on many hardwoods.

Antagonist – organism (usually a pathogen), which doesn't harm the plant and can be used for making a biologically controlled.

Apothecium – a cup or saucerlike sexual fruiting body, which produces ascospores.

Appraisal of the phytosanitary risks – an appraisal of probability, of biological, ecological and/or economic consequences of transferring or distribution of the regulated harmful organisms.

Ascogenous stage – the ascospore producing stage of an *Ascomycete*.

Ascomycete – a large group of fungi that are characterized by free cell formation of spores, usually, eight in number, in a saclike structure called an ascus.

Ascospore – a spore produced in the sexual or perfect fruiting body of an *Ascomycete*.

Asexual stage (imperfect stage) – either a vegetative stage or a reproductive stage in the life cycle of a fungus in which nuclear fusion is absent and in which reproductive spores are produced by mitosis or simple nuclear division.

Autoecious – pertaining to a fungus that completes its life cycle on one host.

Basal cup – the cup-like remnant of a dwarf mistletoe infection that remains visible long after the disintegration of an aerial shoot.

Basidiomycete – a large group of fungi that are characterized by the production of spores, usually four, on a basidium.

Basidiospore – the spore produced by the sexual stage of the *Basidiomycetes*.

Basidium – a cell, usually terminal, in which nuclear fusion and meiosis occur and each of the four haploid nuclei passes into one of four forming spores.

Biocide – a wide spectrum poison that kills a great number and variety of organisms.

Biological control – a method to control regulated harmful organisms using biologically controlled organisms or their natural enemies, antagonists and rivals, which are self produced.

Biologically controlled organism – is a natural enemy, antagonist, rival or any other microphysics item, which is self produced and is used for dealing with regulated harmful organisms.

Biotic – pertaining to living organisms.

Bivoltine is an organism that has two generations per year.

Blight – a general term for plant diseases causing rapid death or dieback.

Brood – all the individuals that hatch at one time from eggs laid by one series of parents. For a population of any species, it refers to all the offspring hatched at about the same time.

Broom – an abnormally dense mass of host branches and foliage in which the typical host growth pattern is lost.

Brown rot – light to dark brown decay of wood that is friable and rectangularly checked in the advanced stage. Caused by fungi that attack mainly the cellulose and associated carbohydrates. The residue is chiefly lignin.

Butt rot – a rot characteristically confined to the butt or lower trunk of a tree.

Cambium – the layer of cells that lies between and gives rise by cell division to the secondary xylem (wood) and the secondary phloem (inner bark).

Canker – a definite, relatively localized, necrotic lesion primarily of the bark and cambium.

Cargo – a certain amount of regulated objects, which are being transferred from one country to another or within Ukraine and for which there is an international phytosanitary or quarantine certificate issued (the cargo can consist of one or more lots).

Chlamydospore – a thick-walled asexual resting spore typically formed by many soilborne fungi.

Chlorosis – an abnormal yellowing of the foliage.

Chlorotic – abnormally yellow.

Chronic – pertaining to a condition that is of long duration.

Colonize – to establish an infection or inhabit a host or part of it.

Conidia – an asexual spore of a fungus typically produced terminally on specialized hyphae termed a conidiophore.

Conidiophore – specialized hypha which produce asexual spores called conidia.

Conk – the large, often bracket-like fruiting bodies of wood-destroying fungi.

Cortex – the primary tissue of a first-year stem or root found between the epidermis and the primary vascular bundle.

Crawler – the active first-instar larva of a scale insect.

Cull factor – a calculated percentage of the amount of merchantable wood lost from a tree as a result of decay or another defect.

Cull – a seedling that is rejected because it does not meet certain specifications.

Cultivar – a variety, selected for one or more outstanding characteristics that are being cultivated and usually reproduced by asexual means to preserve genetic features.

Cultural practices – a general term for those routine nursery operations required to help seedling growth, i.e., plowing, watering, weeding, etc.

Damping-off – the killing of the seedling by microorganisms before emergence or the collapse of the seedling stem at ground level after emergence.

Decay – the decomposition of plant tissue by fungi and other microorganisms.

Decline – the gradual reduction in health and vigor as a tree is in the process of slowly dying.

Deformations – curvature of branches and trunks, curliness of leaves, formation of blown fruits.

Diapause – is the delay in development in response to regular and recurring periods of adverse environmental conditions.

Dieback – the progressive dying, from the tip downward, of twigs, branches, or tops.

Dieback is the progressive dying of stems and branches from the tip downward.

Disease – a violation of normal metabolism in the plant under the influence of phytopathogens (viruses, bacteria, fungi) or adverse environmental conditions.

Disease – unfavorable change of the function or form of a plant from normal, caused by a pathogenic agent or unfavorable environment.

Dominant tree species – a species of trees that has the greatest wood supplies in the first level of a forest stand.

Echinulate – having many small spines or prickles.

Economic threshold of damage – a level of expenditures for performing phytosanitary measures.

Ectoparasite – a parasite (in particular, a nematode) that lives outside its host.

Elements of forest structure of biological significance – components of a forest that are important for the protection, distribution of biotopes and species, or provision of ecological functions.

Elytra – the anterior leathery or chitinous wing covers of beetles.

Endemic – a pest population that is at its usual normal balanced level within a region to which it is indigenous.

Endemic – native to the country or region.

Endoparasite – a parasite (in particular, a nematode) that lives inside its host.

Entrance court – the point of the invasion of a pathogen into its host.

Epidemic – pertaining to pest populations that expand to a level causing disturbances of the normal relationships in the forest association, often to the point of causing economic loss. An epidemic is a disease that has built up rapidly and reached injurious levels.

Epidermis – the outermost layer of cells on the primary plant body.

Exotic – introduced from another country or area.

Extraordinary circumstances – are circumstances, by which the presence of the quarantine organism in the country of origin or transit has been confirmed or suspected, that can cause irreparable harm to the health of plants which are sensitive to this organism all over Ukraine or in a part of Ukraine in the case of importing of objects sensitive to this organism objects which can transfer the quarantined organism.

Exudate – a matter that oozes out or is secreted out.

Facultative saprophyte – an organism that is normally parasitic but which is capable of living as a saprophyte.

Fallow – cultivated land allowed to lie or unplanted during the growing season.

Family – one of the main ranks of hierarchical classification in biological systematics that covers single genus or group of genera that closely or uniformly resemble each other in general appearance and some features.

Flaccid – deficient in turgor, limp, or flabby.

Flags – conspicuous dead branches with foliage remaining on because of rapid killing by adverse abiotic conditions, insects, or disease agents.

Fore wings – are the anterior wings pair (closer to the head).

Forecast – prediction of the spread and development of insects, mites, nematodes, rodents, weeds and plant diseases.

Forest damage – partial or complete loss of the growth potential of a forest stand due to the impact of pests, diseases, animals, humans, wind, snow, fire, and other causes.

Forest inventory – obtaining of information regarding a forest and adjacent marshes, forest infrastructure objects, overflowing clearings, marshes and glades that are part of the forest and in the ownership or possession of the specific forest, and documentation of the obtained information.

Forest land – land covered by a forest, land under forest infrastructure objects, as well as overflowing clearings, marshes, and glades that are part of the forest and adjacent marshes.

Forest protection – measures for prevention or reduction of forest damage and consequences thereof.

Forest reproductive material – a seed unit (cones, fruits, and seeds obtained therefrom and intended for the growing of planting stock), parts of plants, or planting stock (from seed units, parts of plants, or plants from natural regeneration) of the tree species and their hybrids which are important for forestry purposes and intended for reforestation or afforestation.

Forest stand – a forest with uniform forest site conditions, and tree species composition.

Frass – solid excrement of insects; wood residues left by boring insects.

Fruiting body – any of a number of reproductive structures that produce spores.

Fumigation – applying vapor or gas, especially for disinfecting or killing pests.

Fungi imperfecti – a grouping of miscellaneous fungi which lack a known sexual stage and which are classified, therefore, according to the characteristics of their asexual stages.

Fungicide – a chemical that is toxic to fungi.

Fungus mat – a dense, leathery mass of fungus mycelium often formed in decayed wood by certain wood rotting fungi.

Gall – enlarged, swollen growth of plant tissue, a pronounced swelling on a woody plant caused by certain fungi, bacteria, insects, or nematodes.

Gallery – a passage, burrow, or mine excavated by an insect in plant tissue for feeding, oviposition, or exit.

Geniculate – bent abruptly at an angle, like a knee.

Genus – a group of species that have fundamental traits in common but that differ in other, lesser characteristics.

Germinate – to begin growth from a seed or spore.

Girdle – to destroy or remove the tissue, particularly living tissue in a rough ring around a stem branch or root.

Harmful organism – any kind, strain or biotype of plants, animals, pathogenic agents that are harmful to plants or products of the vegetable origin including insects, funguses, bacteria, viruses, eelworms and weeds.

Head – is the anterior section of the insect's body (comprised of a head, thorax, and abdomen) and includes the mouth, eyes, and antennae (if present).

Heart rot – a decay characteristically confined to the heartwood.

Heteroecious – pertaining to a fungus that must pass a part of its life cycle on each of two different unrelated hosts, i.e., some rust fungi.

Hind wings – are the posterior pair (furthest from the head).

Honeydew – sugary liquid excretion of aphids and scales.

Host – a plant or animal on or in which a pathogen or insect exists.

Host range – all hosts that a particular pathogen attacks.

Host-specific – a term used to describe certain disease organisms that attack only certain host species.

Host-specific – a term used to describe those pathogens that attack only certain species of hosts.

Hyaline – transparent, having no color.

Hypha – one of the filamentous threads that make up the fungus body.

Hypocotyl – that part of the axis of a developing embryo just below the cotyledons.

Hysterothecium – a specialized fruiting body of needle-cast fungi that produce ascospores, is usually elongate, covered, and opens at maturity by a long slit.

Imperfect stage – that part of the life cycle of fungi in which only conidia and no sexual spores are produced.

Incipient rot – the early stage of wood decay in which the wood is invaded and may show discoloration but is not otherwise visibly altered.

Indigenous – native to a particular region or environment.

Infect – to invade and cause disease.

Infection – a regulated harmful organism living in a regulated object that is a threat for plants.

Inoculate – to place a pathogen on or in a host in a position in which it is capable of causing disease.

Inoculum – the spores, mycelium, sclerotia, or other propagules of a pathogen that initially infect a host or crop.

Inspection – a visual examination of the regulated objects for determining the presence of the regulated harmful organisms and/or their correspondence to phytosanitary rules. The collection and registration of observation data, monitoring and other procedures related to the determination of the presence or absence of the regulated harmful organism in this area (natural habitat).

Integrated plant protection – comprehensive application of methods for long-term regulation of development and spread of pests to an intangible economic level based on the survey, forecast, economic thresholds of harmfulness, action of beneficial organisms, energy saving, and environmental technologies that provide reliable plant protection and ecological balance.

Intracellular – lying or growing within the cells.

Larva – an immature form of an insect such as a caterpillar, grub, or maggot, insects that undergo complete metamorphosis, like *Lepidoptera* whose larvae are called caterpillars, the larval stage follows hatching from an egg and precedes pupation Compare to nymph. During the larval stage, the organism feeds and undergoes a series of molts until it is ready to pupate in order to metamorphose to the adult stage.

Latent infection – an established infection that does not show its presence.

Leaf spot – a leaf disease characterized by numerous distinct lesions.

Lesion – a defined necrotic area.

Liquidation – elimination of the regulated harmful organisms in accordance with the requirements of the phytosanitary measures.

List A1 – list of quarantined organisms, which are absent in the countries – members of the European and Mediterranean organization of plant protection (EOPP).

List A2 – list of the quarantined organisms, present at least in one country – member of (EOPP), but are not widespread, that are officially controlled (localized).

Localization – realization of phytosanitary measures with the purpose of prevention of the distribution of the regulated harmful organism.

Macroconidia – the larger of two types of conidia produced by certain fungi, such as *Fusarium* species.

Maggot – a legless larva without a well-defined head.

Methods of plant protection – methods by which plant protection is carried out (organizational and economic, agrotechnical, selection, physical, biological, chemical and others).

Microconidia – the smaller of the two types of conidia produced by certain fungi.

Microsclerotium – a very small (microscopic) sclerotium.

Mined foliage – needles or leaves in which the inner leaf tissues are eaten by insects.

Monitoring – an official lasting process for the verification of the phytosanitary state or the status of harmful organisms.

Moribund – being in a dying state.

Mummification – replacement of plant organs with the mycelium of the fungus.

Mycelial fans – similar in structure to mycelial felts but fan-shaped.

Mycelial felt – a mass of fungus filaments that are arranged in a flat plane and resemble a thin felt-like paper or cloth.

Mycelium – a mass of hyphae that form the vegetative filamentous body of a fungus.

Necrosis – death of plant cells usually resulting in darkening of the tissue.

Nymph – immature stage of an insect resembling the adult except for incomplete wing development.

Nymph – in insects, which undergo incomplete metamorphosis. The nymph stage follows hatching from an egg and precedes the adult stage. During the nymph stage, the organism feeds and undergoes a series of molts until it is ready to metamorphosis to the adult stage.

Obligate parasite – a parasite incapable of existing independent of live host tissue.

Oospore – the sexually produced resting spore of the water molds.

Other felling – a type of felling which is used if felling is necessary for the establishment and maintenance of the forest infrastructure and delimiting boundaries, removal of dangerous trees, and preservation of natural values.

Outgrowths (galls, caps, suvelvali) – pathological growth of plant organs with the formation of tumors.

Parasite – an organism living on, in, or with another living organism for obtaining food.

Parasite – an organism living on and nourished by another living organism.

Parasitoids – are organisms that spend most of their development (in the larval stage) on the surface or inside their only host, which is gradually killed during their development. Unlike parasitoids, parasites do not kill the host.

Parts of plants – stem, leaf and root cuttings, explants or embryos for micropropagation, buds, layers, roots, scions, sets and any parts of a plant intended for the production of planting stock.

Pathoentomological survey – is carried out to control the emergence, development, and spread of forest pests and diseases, their foci, the forest health condition, forecasts of possible threats and timely planning, effective organization and implementation of forest protection measures.

Pathogen – an organism that causes a disease.

Pathogenic – capable of causing a disease.

Perennial canker – the recurrent yearly killing back and healing over of the bark and cambial tissues of woody plants by certain disease organisms.

Perfect stage (sexual stage) – the stage in which the sexual spore stage is produced.

Perithecium – a closed flasklike sexual fruiting body formed by certain *Ascomycetes* in which ascospores are produced.

Pests – living organisms (insects, mites, microorganisms, nematodes, rodents), capable of causing damage to plants, shrubs, trees, and products of plant origin. Pest damage is economically feasible to avoid.

Phelloderm – the parenchymatous type of tissue produced to the inside by the cork cambium.

Phellum – the suberized tissue produced by the cork cambium in the bark.

Phloem – the tissues of the inner bark responsible for the transport of nutrients.

Photolytic – pertaining to the chemical decomposition due to the action of sunlight (radiant energy).

Phycomycete – a group of lower fungi that includes water molds.

Phytosanitary condition – complex of pests, their abundance, severity of damage and potential threat.

Phytosanitary certificate – the certification of the phytosanitary state of the regulated objects.

Phytosanitary diagnostics – principles, methods, signs, technical means by which the species of insects, mites, nematodes, rodents, weeds and pathogens are identified.

Phytosanitary examination – a check out and analysis of the regulated objects in the laboratory regarding the presence or absence of the regulated harmful organisms.

Phytosanitary measures – any activities, including all correspondent laws, normative-legal deeds, phytosanitary rules, requirements and procedures which are obligatory for institutions of state governing and personnel implementation.

Phytosanitary procedure – a procedure, established by the institution of the central governing of the executive authority regarding agrarian policy in the field of quarantine of plants, and a method of application of the phytosanitary rules, including performance of the observation, examination, analysis, inspection and control of the uninfected regulated objects.

Phytosanitary rules – rules established by normative-legal deeds for transferring and/or distribution of the quarantined organisms and prevention and restriction of the economic influence of the regulated non-quarantine organisms, including procedures of the phytosanitary certification.

Phytosanitary state – the presence or absence of the regulated harmful organisms in the regulated objects.

Phytotoxic – a chemical that is toxic to plants.

Pitch tube – a tubelike accumulation of pitch around a bark beetle entrance hole on the bark.

Plant protection – a set of measures aimed at reducing crop losses and preventing the deterioration of agricultural and other plants, perennial and forest stands, trees, shrubs, indoor vegetation, and plant products.

Plant protection products – preparations that contain one or more active substances and are used to protect plants or crop products from harmful organisms and the destruction of unwanted plants or parts of plants.

Plaques – mycelium and sporulation of fungi. Non-infectious plaques occur due to the deposition of dust particles on plant organs, industrial emissions, etc.

Pocket rot – a characteristic pattern of rot caused by certain fungi. The rot occurs in distinct, scattered pockets within the heartwood of a tree rather than in a distinct column.

Predator – an organism that attacks, kills, and feeds on other organisms.

Predicting the mass propagation of pests and the spread of forest pathogens is to determine the potential threat of trees and stand damage or mortality in order to timely implement preventive and active measures.

Procedure of verification – any activities to define the phytosanitary state of the regulated objects.

Proper level of the phytosanitary defense – the level of protection, defined for the performance of the phytosanitary measures.

Predisposition – the effect of one or more environmental or biotic factors that makes a plant vulnerable to attack by a pathogen or insect.

Prolegs – fleshy false legs on the abdomen of caterpillars.

Protection measures include a set **of measures** – forestry, biological, chemical, physical and mechanical, breeding and genetic, etc.

Pupa (pl. pupae) – inactive stage of an insect which undergo complete metamorphosis, like Lepidoptera, the pupal stage follows the larval stage and precedes the adult stage. A transition stage from larva to adult. The insect does not feed during this time and is often encased in a cocoon.

Pustules – different sizes and shapes sores and lesions.

Pycnidiospore – an asexual spore or conidium produced within a pycnidium.

Pycnidium – an asexual type of fruiting body, typically flask-shaped, in which asexual spores or conidia are produced.

Pycniospore – a specialized spore produced in a pycnium by rust fungi.

Quarantine – a keeping of the regulated objects in certain places for monitoring or further inspection, phytosanitary examination and/or processing.

Quarantine permission (for import or transit) – an official document, that allows import or transit of the regulated objects according to defined phytosanitary measures.

Quarantine zone – a territory, where quarantine system is established as a result of the detection of the quarantine organism.

Quarantine supervision – supervision of the import cargo after the completion of the customs register/arrangement and/or removing/exporting from the quarantine zone to the destination station.

Quarantine organism – a harmful organism, which in the case of spreading or limited distribution on the Ukrainian territory can inflict significant damage to the plants and plant.

Quarantine of plants – a system of measures, oriented for the prevention of spreading or distribution regulated harmful organisms or providing control over them (localization).

Quarantine system – a special legal structure that foresees a system of phytosanitary measures, which are carried out in the quarantine zone with the purpose of localization and liquidation of quarantine organisms.

Quarantine certificate – a document, issued by the institution of the State service of quarantine of plants of Ukraine and certifies the phytosanitary state of the regulated objects, that have been exported and/or imported into the quarantine zone, transported throughout the Ukrainian territory.

Regulated harmful organism – a quarantine organism or regulated nonquarantine harmful.

Regulated non-quarantined harmful organism – is not a quarantined harmful organism, the presence of which in the seed or planted material exists an unacceptable economic influence on the expected use of these plants and is as a result subjected to regulation.

Regulated objects – any plant, product of the plant origin, place of storage, packing, means of transportation, containers, soil and any other organisms, objects or materials, which are able to carry or diffuse the regulated harmful organisms.

Regulated zone – a zone, where phytosanitary measures are performed with the purpose of prevention of the transferring and/or distribution of the quarantine organisms during import or export of the regulated object.

Resinosis – the unnatural and profuse flow or accumulation of resin from conifers injured or attacked by insects and pathogens.

Resistant – able to withstand without serious injury, attack by an organism, or damage by a nonliving agent but not immune from such attacks.

Rhizomorph – a specialized thread- or cord-like structure made up of parallel hyphae with a protective covering.

Root crown – the uppermost portion of the root system where the major roots join at the base of the stem.

Rot – characterized by softening and destruction of certain parts of plant organs with loss of strength.

Sanitary felling – a type of felling to improve the health condition of a forest by felling trees damaged by forest diseases, pests, animals, broken by wind, etc.

Saprophyte – an organism using dead organic material as food.

Sclerotium – a firm frequently rounded multicellular resting structure produced by fungi.

Septate – having cross walls that divide hyphae or spores into a number of separate cells.

Septum – the cross wall which divides a hypha or spore into two or more distinct cells.

Seta – a bristlelike hair.

Sexual stage (perfect stage) – the stage in the life cycle of a fungus in which spores are produced after sexual fusion.

Skeletonized foliage – leaves or needles in which insects have eaten the soft tissues between the veins.

Special regime of plant protection – a special legal regime of local executive bodies and local governments, enterprises, institutions and organizations, aimed at localization and elimination of especially dangerous pests and diseases within the settlement, district, region, or several regions.

Species – a natural group (of fungi, insects, or bacteria) in the same genus made up of similar individuals.

Spore – the reproductive structure of fungi and lower plants.

Sporulate – to produce and release spores.

Spots – are characterized by the formation of spots of different sizes, shapes, colors and texture on plant organs.

Spreader – a chemical additive to fungicide sprays to improve their distribution on the plant foliage.

State supervision – an activity of the state governing institutions regarding quarantined plants that is made periodically, with a purpose of ensuring that the personnel of phytosanitary measures follow the process of producing, saving, transporting, utilizing, including exporting and importing of regulated objects, established by the legislation.

Status of the harmful organism (in a zone) – recognizing by the state institutions in the field of quarantine of plants of the presence or absence of the harmful organism in the zone at the present time, including necessary data concerning its geographical distribution, on the basis of expert opinion, that is based on current and previous reports regarding the harmful organism and other information.

Sticker – a chemical additive to fungicide sprays to improve the fungicide's retention on the plant surface.

Stoma (pl. stomata) – a pore in the leaf epidermis, surrounded by two guard cells, leading into an intercellular space within the plant.

Stroma (pl. stromata) – a cushionlike body on or in which fungus fruiting bodies are formed.

Supervision – a process of collecting and registering data concerning the presence or absence of the regulated harmful organism in the defined zone by the state institutions regarding quarantine of plants by means of observation, monitoring and others procedures.

Survey and assessment – is carried out in order to identify and evaluate the abundance and spread of pests and pathogens, as well as forest health condition.

Susceptible – unable to withstand attack by an organism or damage by a nonliving agent without serious injury.

Sustainable forest management – forest management and use in such a manner and intensity which maintain the biological diversity, productivity, regenerative capacity, viability, and potential of the forest at present and in the future, its ability to fulfill the significant ecological, economic, and social functions on a local and global scale without damage to other ecosystems.

Symptoms – the noticeable evidence of disturbances in the normal development and life processes of the host plant.

Systemic – affecting or distributed throughout the whole plant body.

Taproot – the primary descending root of a plant that has secondary or lateral roots.

Tar, mucus, gum disease – intense secretion of resin, gum and mucus at the site of injury.

Teliospore – the spore of the rust fungi from which the perfect stage of the basidium and basidiospore arise.

Telium – an aggregation of teliospores of the rust fungi.

The center for the quarantine of plants – a specially equipped place, where the phytosanitary state of the object of regulation is defined.

The definition of the phytosanitary danger – a process of defining the amount of regulated harmful organisms that can be potentially transferred to the territory of Ukraine by means of importing regulated objects.

Thorax – the middle section of insect body. In adult *Lepidoptera* and *Odonata*, the wings and legs are attached to the thorax.

Tracheomycosis (vascular mycosis) – blockage of blood vessels by the mycelium of fungus and its products.

Translocation – the transfer of elaborated food materials within the plant.

Tubercle – a small rounded projection from the surface of an insect.

Ulcers are the f wounds on plant organs, surrounded by influx. Large ulcers are called cancerous ulcers, and small – anthracnose.

Urediospores – one of the many spore stages produced by the rust fungi in their complicated life cycle. These spores are produced in a fruiting body called a uredium.

Uredium – one of the many types of fruiting bodies formed by the rusts in their complicated life cycle. Urediospores are formed in this fruiting body.

Variety – a subdivision of a species having a distinct, though often inconspicuous, difference and breeding true to that difference.

Vector – a carrier of a disease-producing organism.

Weeds – unwanted vegetation in lands, crops, plantings, which competes with them for light, water, nutrients, as well as contributes to the spread of pests and diseases.

Wetwood – a discolored, water-soaked condition of the heartwood of some trees presumably caused by bacterial fermentation.

White rot – decay caused by fungi that attack all chief constituents of wood and leave a whitish or light colored residue.

Wilt – type of plant disease characterized by the sudden loss in turgor and collapse of the succulent parts of the affected plants.

Witches broom – an abnormally profuse, dense mass of host branches and foliage. This is a common symptom induced by dwarf mistletoes as well as other parasitic and abiotic agents.

Witch's broom – intensive growth of shortened shoots from dormant buds with the formation of a bush.

Withering – water imbalance in the plant with loss of turgor pressure. Withering can be caused by infectious or non-infectious factors. Infectious wilting (childhood seedling disease, blackleg) occurs as a result of various pathogens, most often fungi.

Xylem – the woody conducting tissues of stem and roots.

Zone, free of regulated harmful organisms – a zone, where the absence of the regulated harmful organism is scientifically confirmed and this condition is officially maintained during a certain defined period of time.

Zone with the insignificant amount of the regulated harmful organisms – a zone which is defined by the State quarantine of plants service of Ukraine, where the regulated harmful organism is present in an amount, that exceeds the economic threshold of damage, and is under their supervision, control and/or destruction.

Zoospore – a motile free swimming spore produced by the water molds.

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SUPPLEMENTS

Supplement A

THE FOREST CODE OF UKRAINE

Date of entry into force:
April 13, 1994

The Law of Ukraine "On Amending the Forest Code of Ukraine" No. 3404-IV of 8 February 2006 shall render the Forest Code of Ukraine in a new wording. The new wording of the Forest Code of Ukraine came into force on March 29, 2006.

According to the Code, forest shall be a type of natural system which mainly consists of trees, brushwood vegetation, the relevant soils, herbaceous vegetation, fauna, microorganisms, and other natural components that are interrelated in their development and influence each other and the natural environment.

Relations dealing with forest shall be social relations that are linked to ownership, use and disposal of forests and shall aim at ensuring protection, reproduction and sustainable use of forest resources with due consideration for environmental, economic, social, and other interests of the society.

The forest fund of Ukraine shall include forest plots, including protection plants of linear type, with the area of no less than 0.1 hectare. The forest fund shall not include:

– green plantations within the limits of settlements (parks, gardens, public gardens, boulevards, and so on) that are not included into forests according to the established procedure;

– separate trees and groups of trees, brushwood on agricultural lands, homesteads, country land plots, and garden plots.

Forests located within the border of the Ukrainian territory shall be objects of ownership right of the Ukrainian People. On behalf of the Ukrainian People, rights of owners for forests are exercised by government bodies and bodies of local self-government. Forests can be state, communal and private property. Subjects of ownership right for forests shall be the state, territorial communities, citizens, and legal entities. Subjects of private ownership right for forests shall be citizens and legal entities of Ukraine.

The right to use forests shall be exercised according to the procedure for permanent and temporary use of forests.

Articles 26–33 of the Forest Code shall establish powers of government bodies and bodies of local self-government in the area of relations dealing with forest.

By environmental and socio-economic aspects and depending on the main functions that they fulfil, Ukrainian forests shall be divided into the following categories:

– protection forests;

– recreation and relaxation forests;

– forests for environmental, scientific, historical, and cultural purposes;

– operational forests.

The Forest Code shall envisage keeping of the State Forest Cadastre. On the Ukrainian territory, the State Forest Cadastre shall be kept for the purpose of effectively organizing guarding and protection of forests, rationally using the forest fund of Ukraine, reproducing forests, exercising systematical control over qualitative and quantitative changes in forests.

Monitoring of forests shall be a system for regular supervision, evaluation of and forecast for the dynamic of the qualitative and quantitative condition of forests.

Section 11 of the Forest Code shall envisage the procedure for changing targeted designation of land forest plots and identifying the places for building objects that influence the state and reproduction of forests.

The procedure for managing forests shall be identified by Chapter V.

Forest resources can be used according to the procedure for general and special use of forests.

Citizens shall have the right to freely stay in forests, to collect wild grasses and herbs, flowers, berries, nuts, and mushrooms in forests that are in state and municipal ownership without a special permit and free of charge, as well as upon consent of the owner of forests that are private property.

According to the procedure for special use of forests, the following types of use of forest resources can be carried out:

– logging of timber by felling and chopping forests for the main use;

– logging of secondary timber;

– by-activity in using forests;

– use of useful properties of forests for cultural, recreational, relaxation, sport, tourist, educational, and upbringing purposes, needs of hunting, and the implementation of scientific works.

Special use of forest resources at the allocated forest plot shall be carried out on the basis of a special permit. Such a special permit shall be issued:

– by a body of executive power in the area of forestry of the Autonomous Republic of Crimea;

– by territorial bodies of the central body of executive power in the area of forestry;

– owners of forests;

– regular forest-users.

Section 16 of the Forest Code shall be dedicated to the protection and guarding of forests. Protection and guarding of forests shall envisage a set of measures aimed at protecting forests against fires, illegal felling and chopping, damages, weakening, and other harmful impact, protecting against vermins, pests and diseases. Owners of forests and regular forest-users shall be responsible for developing and implementing a set of fire prevention and other measures aimed at preserving, protecting and guarding forests within an established period of time.

Protection and guarding of forests on the territory of Ukraine shall be carried out:

– by the State Forest Protection Service that operates under the central body of executive power in the area of forestry, the body of executive power in the area of forestry of the Autonomous Republic of Crimea, territorial bodies of the central body of executive power in the area of forestry, as well as enterprises, institutions and organizations that belong to the area of its management;

– by forest protection services of other regular forest-users and owners of forests.

The State Forest Protection Service shall have the status of a law enforcement body. Powers of officials of the State Forest Protection Service shall be specified by Article 91 of the Forest Code.

According to Article 93 of the Forest Code, the objectives of controlling the protection, guarding, utilization, and reproduction of forests shall be:

– to ensure the implementation of government policy in the area of protecting, guarding, using, and reproducing forests;

– to ensure the adherence to the legislation related to forests by government bodies, bodies of local self-government, enterprises, institutions, organizations, and citizens;

– to ensure the adherence to the legislation related to forests by owners of forests, regular and temporary forest-users;

– to prevent violations of the legislation in the area of protecting, guarding, using, and reproducing forests, to ensure timely detection of such violations and to ensure the relevant measures to eliminate such violations.

State control of the protection, guarding, use, and reproduction of forests shall be carried out:

– by the Cabinet of Ministers of Ukraine;

– by the central body of executive power in the area of protecting the natural environment;

– by the central body of executive power in the area of forestry;

– by bodies of executive power in the area of forestry and in the area of protecting the natural environment of the Autonomous Republic of Crimea;

– by territorial bodies of the central bodies of executive power in the area of protecting the natural environment;

– by territorial bodies of the central bodies of executive power in the area of forestry;

– by other central and local bodies of executive power within the limits of powers established by the law.

Measures aimed at raising the productivity, improving the quality composition of forests, protection, guarding and reproduction of forests shall be financed at the expense of:

– the State Budget and funds of enterprises, institutions and organizations of forestry – with respect to forests that are state property;

– local budgets and funds of enterprises, institutions and organizations of forestry – with respect to forests that are communal property;

– funds of private owners of forests – with respect to forests that are private property.

The country shall provide economic incentives for implementing measures aimed at expanded reproduction of forests specifically by way of:

– compensating expenditures to owners of forests and forest-users that are linked to measures aimed at expanded reproduction of forests implemented thereby;

– applying accelerated depreciation to fixed assets for land protection, forest protection and environmental protection purposes.

Peculiarities of protecting, guarding, using, and reproducing forests on specific categories of lands shall be established by Chapter (Section) 20 of the Forest Code.

Disputes related to the protection, guarding, use, and reproduction of forests shall be resolved:

– by bodies of local self-government (disputes related to the protection, guarding, use, and reproduction of forests that are communal property);

– by bodies of executive power in the area of forestry (disputes related to the protection, guarding, use, and reproduction of forests that are state property);

– by bodies of executive power in the area of protecting the natural environment (disputes related to the protection, guarding, use, and reproduction of forests that are state property);

– by courts (disputes related to ownership, use and disposal of forests that are private property of citizens and legal entities).

If owners of forests and forest-users do not agree to a decision of bodies of executive power in the area of forestry and in the area of protecting the natural environment or a body of local self-government, such a dispute shall be resolved by a court (Article 103 of the Forest Code).

According to Article 105 of the Forest Code, responsibility for violating the legislation related to forests shall be born by individuals and entities that are guilty of:

– illegal felling, chopping and damaging trees and brushwood;

– destroying or damaging forests as a result of setting forests on fire or carelessly treating fire, and violating other requirements to fire safety in forests;

– destroying or damaging forests as a result of contaminating them with chemical and radio-active substances, industrial and residential wastes, waste waters, and other harmful substances, water-logging, dewatering, and other types of harmful impacts;

– littering forests with residential and industrial wastes;

– violating the deadlines for reforestation and other requirement to forestry established by the legislation in the area of protecting, guarding, using, and reproducing forests;

– destroying or damaging forest cultures, seedlings or young plants in forest nurseries and on plantations, as well as natural underbrush and self-sown plants on lands designated for reproduction of forests;

– violating the rules for storing, transporting and applying means for the protection of forest, growth stimulators, mineral fertilizers, and other substances;

– stubbing out forest plots and using them not according their targeted designation, including for constructing residential houses, industrial and other building and structures without the relevant permit;

– laying up hay and pasturing cattle on forest plots without the relevant authorization;

– violating the rules for laying up forest floor, medicinal plants and herbs, wild fruits, nuts, mushrooms, berries, and so on;

– logging forest resources by means that negatively affect the state and reproduction of forests;

– violating the procedure for logging and removing timber, laying up turpentine, and using other forest resources;

– failing to make payments for using forest resources within the established deadlines;

– destroying and damaging land-marks and posts in forests;

– putting into operation new and reconstructed enterprises, facilities and other objects that are not supplied with equipment that prevents negative impact for the state and reproduction of forests;

– violating the deadlines for returning forest plots that are in temporary use or failing to fulfill the obligations to bring them into condition that is suitable and fit to ensure their designated use;

– damaging hayfields, pastures and tillage on agricultural lands;

– destroying or damaging forest drainage furrows, drainage systems and roads on forest plots;

– failing to implement instructions of the State Forest Protection Service and bodies of executive power that exercise control over the adherence to the legislation in the area of protecting, guarding, using, and reproducing forests.

According to Article 106 of the Forest Code, land plots for forestry purposes and other land forest plots occupied without permission shall be returned to their owners without compensation of expenditures sustained during the period of unauthorized use of such plots.

On the basis of Article 108 of the Forest Code, illegally acquired timber and other forest resources shall be subject to withdrawal. If it is impossible to withdraw illegally acquired timber and other forest resources, their cost shall be collected from the relevant individuals and entities.

Supplement B

LAW ON PLANT PROTECTION

The Law consists of 5 Sections composed of 29 articles.

Section 1 (arts. 1-2) lays down general provisions.

Section 2 (arts. 3-20) regards state regulation in the sphere of plant protection.

Section 3 (arts. 21-23) establishes liability and regulates dispute settlement.

Section 4 (arts. 24-29) regards scientific and financial coverage of the plant protection arrangements.

Section 5 lays down final provisions. The present Law regulates legal relations connected with protection of agricultural, perennial, forest plants, shrubbery, plantations, phytogenous products against pests, diseases and weeds, determines the rights and the duties of enterprises, institutions, organizations of all forms of property and citizens, establishes the plenary powers of the executive bodies and officials. The main principles of the state policy in the sphere of plant protection shall be:

1) state policy building in the sphere of plant protection;

2) state supervision over plant protection;

3) priority of the application of integrated pest management and other ecologically safe plant protection arrangements (art. 3).

The main plant protection requirements shall be:

1) observance of plant growing technologies;

2) ecological and economic substantiation of the utility of plant protection against pests;

3) obligation to carry out plant protection arrangements by all land tenants, water users and farmers;

4) strict observance of the regulations on transport and rage of pesticides;

5) conservation of beneficial flora and fauna; 6) prevention of annihilation and damage to plants (art. 4).

Special plant protection procedure (quarantine) shall be introduced on the territory of a determined area in case of mass propagation of especially dangerous pests for the purpose of the localization and liquidation thereof (art. 14).

Liability shall be established for the following offences:

1) propagation of pests caused by the breakdown of the process of plant growing;

2) application of plant protection arrangements without environmental substantiation;

3) infringement of the legislation on plant protection;

4) failure to report or incorrect reports on hazard to crops and plantations by the propagation of pests;

5) import and trade of pesticides that have non been tested and haven't passed state registration;

6) failure to execute legal requirements of the authorized officials in the sphere of plant protection (art. 21).

Supplement C

THE LAW OF UKRAINE
ON PLANT QUARANTINE

This Law determines the general legal, organizational, financial and economic basis of plant quarantine, activities of the state bodies, enterprises, institutions, organizations, officials and citizens aimed at preventing the entry and spreading of dangerous pests, plant diseases and weeds, which are not present in the territory of Ukraine.

CHAPTER I
GENERAL PROVISIONS

Article 1. Definition of Terms

The terms set out below in this Law are used in the following meaning:

– plant quarantine – a legal regime which provides for the system of government measures aimed at the protection of plants, products of their processing, raw materials, individual shipments, etc. from the quarantine objects;

– special quarantine regime – a special legal regime of activities of the state bodies, bodies of local and regional selfgovernment, enterprises, institutions and organizations aimed at the localization and liquidation of the seats of quarantine objects which allows the temporary introduction of restrictions provided for by this Law on the citizens' rights and rights of legal entities, and assigns additional obligations upon them;

– quarantine object – pests, agents of a plant disease or a weed that is not present or is present in limited quantities on the territory of Ukraine, but which may pose a significant threat to the plants or vegetable products.

The Ministry of Agriculture and Food of Ukraine shall determine a list of quarantine objects.

Materials and objects subject to quarantine – any materials and objects that may cause or facilitate the spread of quarantine objects.

A list of materials and objects subject to quarantine shall be determined by the Statute of Plant Quarantine in Ukraine to be approved by the Cabinet of Ministers of Ukraine.

Quarantine zone – a territory where the special quarantine regime is established due to the revealed quarantine objects.

Article 2. Basic Goals of Plant Quarantine

The basic goals of plant quarantine are:

– protection of the country's territory from bringing in or independent entry of quarantine objects from abroad or from the quarantine zone;

– timely disclosure, localization and liquidation of quarantine objects, as well as the prevention of their spread to those regions of the country that are free from them;

– implementation of the state control over observance of the special quarantine regime and implementation of the plant quarantine measures during the process of cultivating, procurement, exporting, importing, transporting, storing, processing and utilizing the materials and objects subject to quarantine.

Article 3. Legislation on Plant Quarantine

The legislation on plant quarantine shall be based on the Constitution of Ukraine and shall embody the present Law and other legislative acts adopted in accordance with this Law.

CHAPTER II
STATE REGULATION OF PLANT QUARANTINE

Article 4. Bodies Exercising State Regulation of Plant Quarantine

State regulation of plant quarantine shall be carried out by the Verkhovna Rada of Ukraine, the Cabinet of Ministers of Ukraine, the Verkhovna Rada and the Council of Ministers of the Republic of Crimea, and by the specially authorized state bodies on plant quarantine, other state bodies and bodies of local and regional self-government in the order established by the legislation.

Article 5. Specially Authorized Bodies on Plant Quarantine

The central specially authorized state body on plant quarantine is the Chief State Inspection on Plant Quarantine of Ukraine with the Central Research and Development Quarantine Laboratory and the Central Fumigation Detachment of the Ministry of Agriculture and Food of Ukraine.

Other special bodies of plant quarantine that are subordinate to the Chief State Inspection on Plant Quarantine of Ukraine is the state inspection on plant quarantine of the Republic of Crimea, border oblasts inspection, or oblast and city inspections on plant quarantine, plant quarantine stations in the sea and river ports (in docks), on the railway stations and in airports (at airfields), at post offices, on highways (at bus stations, bus terminals), at border posts on the state border of Ukraine, laboratories and regional fumigation detachments.

The plant quarantine stations may be established, where necessary, at other objects, the activities of which are related to the procurement, exporting, importing, transportation and utilization of materials and objects subject to quarantine.

The organizational structure and the number of employees of the state service on plant quarantine shall be approved by the

Ministry of Agriculture and Food of Ukraine upon presentation of the Chief State Inspection on Plant Quarantine of Ukraine.

Article 6. Competence of the Chief State Inspection on Plant Quarantine of Ukraine

The competence of the Chief State Inspection on Plant Quarantine shall be as follows:

1) directing the activity of the Central Research and Development Quarantine Laboratory and the Central Fumigation Detachment, the border state inspection on plant quarantine of the Republic of Crimea, the border oblast, oblast and city state inspections on plant quarantine;

2) establishing the procedure for bringing in and utilization of seed, plants and products of plant origin from abroad, their transportation within the territory of Ukraine and beyond its borders in coordination with the quarantine services of the countries with which Ukraine has concluded the treaties, on the basis of a convention or an agreement on cooperation between the states;

3) researching the varieties, biology and ecology of the quarantine object and other dangerous pests, the diseases of plants and weeds that are not present in the country's territory, developing forecasts of their spreading in order to prevent their entry to those regions where they may cause damage;

4) issuing relevant instructions, regulations, rules, orders and other normative documents on plant quarantine;

5) keeping records and informing on the spread of the quarantine objects;

6) conducting an expertise of the materials and objects subject to quarantine;

7) issuing quarantine documents for the import of seed, plants and products of plant origin;

8) submitting proposals to the Cabinet of Ministers of Ukraine regarding the introduction of the special quarantine regime;

9) coordinating together with the Ministry of Agriculture and Food of Ukraine and the Ukrainian Academy of Agrarian Sciences, the research and development activities on plant quarantine;

10) exercising control over compliance with the legislation on plant quarantine, including the process of signing agreements (contracts) on delivery of products of plant origin from abroad;

11) publicizing knowledge on plant quarantine;

12) state control over the implementation of quarantine measures by enterprises, institutions, organizations and citizens.

The State Service on Plant Quarantine shall carry out its activities together with the Security Service of Ukraine, the Ministry of Interior of Ukraine, the State Committee on Guarding the National Border of Ukraine, the State Customs Committee of Ukraine, the local bodies of the state executive power, other state bodies, bodies of local and regional selfgovernment.

Enterprises, institutions, organizations and citizens should assist the state inspectors on plant quarantine in their performance of the duties assigned to them.

The rules of phytosanitary control, issued by the Chief State Inspection on Plant Quarantine of Ukraine within its competence, shall be binding on all state bodies, as well as enterprises, institutions and organizations, officials and citizens.

Article 7. Competence of the Border State Inspection on Plant Quarantine of the Republic of Crimea, Border Oblast Inspections and the Oblast and City Inspections on Plant Quarantine

The border state inspection on plant quarantine of the Republic of Crimea, border oblast inspections and the oblast and city Inspections on plant quarantine shall, within their competence:

1) issue certificates for seed, plants and products of plant origin that are exported or withdrawn from the zones with the special quarantine regime;

2) conduct the quarantine checks and laboratory expertise of materials and objects subject to quarantine delivered from abroad (including those delivered in baggage, postal correspondence and passenger hand luggage);

3) organize the treatment and disinfections of materials, objects and vehicles subject to quarantine that are delivered from abroad;

4) the state control over the implementation of quarantine measures by enterprises, institutions, organizations and citizens;

5) organize the systematic and control examinations of agricultural lands and forests, places of storage and processing of the seed, plants and products of plant origin, of delivery points to which materials and objects subject to quarantine are delivered, as well as of the adjacent territory;

6) control over the activities of the introductory quarantine nurseries, the state-owed strain-testing stations, hothouses and greenhouses, where quarantine testing of seed, plants and cultivated materials delivered from abroad is provided;

7) exercise the state control on production, procurement, transportation, storage, processing, utilization and sales of seed, plants and products of plant origin that are exported or imported; 8) take, according to the legislation, urgent measures in order to localize and liquidate the quarantine objects, and prevent their spreading;

9) control over the implementation of quarantine measures according to the international agreements and conventions;

10) publicizing knowledge on plant quarantine;

11) submit to relevant bodies proposals regarding the introduction (lifting) of the special quarantine regime;

12) attract to their activities the public representatives on plant quarantine from the employees of procurement, transportation, processing, and other enterprises, institutions and organizations.

Article 8. Procedure on Introduction of the Special Quarantine Regime

In case of revealing the quarantine objects the Chief State Inspector of plant quarantine of Ukraine and other state inspectors on plant quarantine shall submit within 24 hours a draft proposal on the introduction of the special quarantine regime, to the relevant body of local or regional self-government, body of the state executive power or to the Cabinet of Ministers of Ukraine.

The territory of the special quarantine regime shall be established by the relevant body of local or regional selfgovernment, the local body of the state executive power within the boundaries of the populated area, district, several districts or oblast, and if it falls within the boundaries of several oblasts, it should be established by the Cabinet of Ministers of Ukraine.

The body that has made a decision on introducing or lifting the special quarantine regime must immediately inform the enterprises, institutions and organizations located on that territory and citizens living on that territory.

A decision, by which a special quarantine regime is established, shall indicate:

– circumstances that caused the introduction of the special quarantine regime;

– boundaries of the territory subject to the special quarantine regime;

– time on which the special quarantine regime is introduced;

– list of quarantine restrictions, measures on localization and liquidation of the quarantine objects.

Article 9. Measures that are Implemented in the Territory with the Special Quarantine Regime

The following measures may be implemented on the territory with the special quarantine regime:

– restrictions on the exit of the vehicles and their inspection;

– utilization of the resources of enterprises, institutions and organizations for localization and liquidation of the quarantine objects with the further compensation for damages;

– prohibition of the removal of relevant materials subject to quarantine;

– disinfections of the materials and objects subject to quarantine;

– technical processing or disposal of the materials subject to quarantine.

Compensation for damages caused as a result of unlawful actions taken by the state bodies and officials that are ensuring the implementation of the quarantine measures, shall be made in accordance with the legislation.

Article 10. The Authority of the Oblast, District Radas of People's Deputies, the City Radas of People's Deputies and Their Executive Committees, Local Bodies of the Executive Power in the Field of Plant Quarantine

The oblast, district Radas of People's Deputies, the city Radas of People's Deputies and their executive committees, local bodies of the executive power shall organize and provide control over implementation of the quarantine measures and, together with the owners or the authorized bodies of the sea and river ports (docks), railway stations, airports (airfields), post offices, bus stations (bus terminals), the officials of the customs-houses and the state border posts, shall create appropriate conditions for the state inspectors on plant quarantine for due performance of their official duties.

Upon submission of the chief state inspectors on plant quarantine or the state inspectors on plant quarantine, these bodies may introduce a special quarantine regime, which can be lifted upon submission of a proposal by the chief state inspectors.

Article 11. Phytosanitary Control

All materials and objects subject to quarantine that cross the state border of Ukraine and the borders of the special quarantine zones shall be subject to phytosanitary control.

Import of materials subject to quarantine into Ukraine shall be allowed if the following documents are available:

– a phytosanitary certificate issued by the state bodies on quarantine and protection of plants of the exporting country;

– quarantine import permit issued by the Chief State Inspection on Plant Quarantine of Ukraine. Customs clearance of cargoes shall be conducted only after the phytosanitary control.

A sample of the phytosanitary certificate and the procedure of its issuance shall be determined by the Chief State Inspection on Plant Quarantine of Ukraine in compliance with the existing international conventions.

The sample of the quarantine import permit and the procedure for its issuance shall be determined by the Chief State Inspection on Plant Quarantine of Ukraine.

Materials subject to quarantine may be exited from the special quarantine zone provided they have a quarantine certificate.

The sample of the quarantine certificate and the procedure of its issuance shall be determined by the Chief State Inspection on Plant Quarantine of Ukraine.

The phytosanitary rules on delivery from abroad, transportation within the country, export and the order of processing of the materials subject to quarantine shall be determined by the Chief State Inspection on Plant Quarantine of Ukraine.

Article 12. Officials Implementing the State Control on Plant

Quarantine Organization and implementation of the state control over plant quarantine of plants is laid upon the chief state inspectors on plant quarantine, their deputies and the state inspectors on plant quarantine.

The Chief State Inspector on Plant Quarantine of Ukraine is the head of the Chief State Inspection on Plant Quarantine of Ukraine, appointed to or dismissed from the position by the Ministry of Agriculture and Food of Ukraine.

The chief state inspector on plant quarantine of the Republic of the Crimea, oblast and the city of Kyiv is the head of the relevant body on plant quarantine appointed to and dismissed from by the Chief State Inspector on plant quarantine of Ukraine.

The chief, leading specialists and the specialists of all categories of border oblast, oblast, city inspections on plant quarantine, the heads of the border posts on plant quarantine in the sea, river ports (in docks), on the respective railway stations, in airports, at the central post-offices or highways are, by their offices, at the same time the state inspectors on plant quarantine of the relevant territory or a post.

Article 13. Obligations and Rights of the Chief State Inspector on Plant Quarantine of Ukraine, the Republic of Crimea, Oblast and the City of Kyiv

1. The Chief State Inspector on plant quarantine of Ukraine, the Republic of Crimea, oblast and the city of Kyiv shall administer the plant quarantine service, exercise the state control and are responsible for the implementation of quarantine measures on the territory of Ukraine, the Republic of Crimea, oblast and the city of Kyiv, respectively.

When exercising the quarantine control the Chief State Inspector on plant quarantine of Ukraine, the Republic of Crimea, oblast and the city of Kyiv, the state inspectors shall have the right to:

– detain the materials and objects subject to quarantine that were removed from the territories where the special quarantine regime is introduced without the quarantine certificates, or those imported from abroad without a quarantine permission, for the period of phytosanitary expertise;

– freely visit the respective objects within the service zone, request information necessary for exercising their authorities;

– provide the sampling of seed, plants, products of plant origin and other materials to carry out a laboratory expertise in compliance with the legislation;

– impose administrative sanctions on the persons guilty of violating the legislation on plant quarantine;

– be supplied with tickets for any type of public municipal and local transport purchased by budget institutions in accordance with the procedure established by the Cabinet of Ministers of Ukraine;

– wear an established type of the uniform.

The samples of uniforms outfit, their lifetime and the supply procedure shall be determined by the Cabinet of Ministers of Ukraine.

2. The Chief State Inspector on Plant Quarantine of Ukraine, the Republic of Crimea, oblast, city/town and state inspector on plant quarantine in case of revealing the quarantine objects on the territory of Ukraine shall submit, within 24 hours, a proposal on the introduction of the special quarantine regime and shall have the right:

– to issue binding instructions on implementations of quarantine measures;

– to detain the transportation vehicles that can facilitate the spread of the quarantine objects;

– to disinfect the materials and objects subject to quarantine;

– to confiscate, liquidate or send the materials subject to quarantine for technical processing;

– to issue relevant conclusions for the insurance bodies.

Article 14. The Guarantees of the Activities of Persons Exercising the State Control on Plant Quarantine

The Chief State Inspector on Plant Quarantine of Ukraine, the Republic of Crimea, oblast and the city, the state inspectors on plant quarantine are independent in performing their activities and shall be guided by this Law, the Statute of Quarantine Service and by other acts of legislation on plant quarantine.

The decisions of the state inspector that are adopted within their terms of reference regarding the prohibition of cultivating, exporting, importing, storing or utilizing the material subject to quarantine shall be binding.

Upon approval of the Chief State Inspector on Plant Quarantine of Ukraine, the Republic of Crimea, oblast and city/town the authorities of the state inspectors on plant quarantine may be partially delegated to the staff employees of procurement, transport, processing and other enterprises, institutions and organizations, and the citizens being public representatives authorized to activities in plant quarantine in compliance with the Provision on Public Representatives.

Article 15. Obligations of Enterprises, Institutions, Organizations, Officials and Citizens on Ensuring the Plant Quarantine

Enterprises, institutions, organizations, officials and citizens the activity of which is related to the production, processing, storing, transportation and trade in materials subject to quarantine should:

– comply with the phytosanitary rules;

– assist, within their competence, the state service on plant quarantine, execute the directives of the state service on plant quarantine with regard to the implementation of the relevant quarantine measures;

– submit upon the request of the state service specialists on plant quarantine the information on the presence of materials and objects subject to quarantine;

– provide, in order to reveal the quarantine objects, a systematic monitoring of crops, storage facilities where materials subject to quarantine are stored and also submit for inspection and expertise the available materials subject to quarantine;

– in case of revealing the quarantine objects immediately inform the state service on plant quarantine, facilitate implementation of the quarantine measures in the special quarantine and adjacent zones;

– when purchasing abroad the large consignments of seed, plants and products of plant origin, delegate, on their own account, the state inspectors on plant quarantine to exercise phytosanitary control in the places where materials subject to quarantine are shipped in Ukraine.

The relevant state bodies, enterprises, institutions, organizations, officials and citizens the activity of which is related to the production, processing, storage, transportation and trade in materials subject to quarantine should provide free of charge the office buildings, necessary equipment, means of communication, and reimburse the expenses on their maintenance and rental fee to the bodies and institutions of the state service on plant quarantine (including those on motor, railway, water and air transport, border posts on plant quarantine, customs offices and the state border posts, plant quarantine points on the markets, post offices, etc.).

Article 16. Liability for Violation of Quarantine Requirements

Citizens and officials guilty of violating the legislation on plant quarantine shall be called to account in accordance with the legislation of Ukraine.

Entrepreneurs guilty of violating the quarantine requirements as to the exit from the quarantine zones or entry from abroad of the materials subject to quarantine shall be fined in accordance with the court procedure upon petition of the chief state inspectors on plant quarantine.

CHAPTER III
FINAL PROVISIONS

Article 17. Professional Requirements to the Specialists in the Field of Plant Quarantine

The citizens of Ukraine who have higher or secondary special education may carry out professional activity in the field of plant quarantine.

The specialists in the field of plant quarantine shall work under a labor agreement (contract).

Professional training of the specialists in the field of plant quarantine with further attestation shall be funded from the state budget once per five years.

The procedure of the specialists' in plant quarantine attestation shall be determined by the Chief State Inspector on Plant Quarantine of Ukraine. The specialists in the field of plant quarantine who have violated their official duties shall be liable in accordance with the legislation of Ukraine.

Article 18. Scientific Support for the State Service on Plant Quarantine

Scientific support for the state service on plant quarantine shall be provided by the Ministry of Agriculture and Food of Ukraine and the Ukrainian Academy of Agrarian Sciences through the network of profile research and development institutes and stations.

Article 19. Phytosanitary Expertise

For the purposes of revealing the quarantine objects in materials and objects subject to quarantine the quarantine laboratories shall conduct the phytosanitary expertise.

Phytosanitary expertise can be carried out repeatedly according to the requirement of concerned person and for the account of this person.

Article 20. Financing of Quarantine Measures

The measures on preventing the spread, localization and liquidation of the quarantine objects, and the control observations of agricultural lands shall be financed from the state budget.

Article 21. Financing and Logistics of the Bodies of State Service on Plant Quarantine

Financing and logistics of the bodies of state service on plant quarantine shall be provided from the state budget and non-budgetary funds.

Scientific support for plant quarantine shall be financed by the Ukrainian Academy of Agrarian Sciences and the Ministry of Agriculture and Food of Ukraine.

Article 22. International Agreements

If the international agreements to which Ukraine is a party establishes the rules other than those provided for by this Law, the rules of that international agreement shall be applied.

PLANT TAXONOMY

NOMENCLATURE	EXAMPLES
DOMAIN	Eukarya
KINDOM	Plantae
PHYLUM	Anthophyta
CLASS	Magnoliopsida
ORDER	Caryophyllales
FAMILY	Droseraceae
GENUS	*Dionaea*
SPECIES	*Dionaea muscipula*

Supplement E

FUNGI TAXONOMY

NOMENCLATURE	EXAMPLES	
DOMAIN	Eukarya	Eukarya
KINDOM	Fungi	Fungi
PHYLUM/ DIVISION	Ascomycota	Basidiomycota
CLASS	Leotiomycetes	Agaricomycetes
ORDER	Erysiphales	Boletales
FAMILY	Erysiphaceae	Boletaceae
GENUS	*Erysiphe*	*Boletus*
SPECIES	*Erysiphe alphitoides*	*Boletus edulis*

Supplement F

INSECTS TAXONOMY

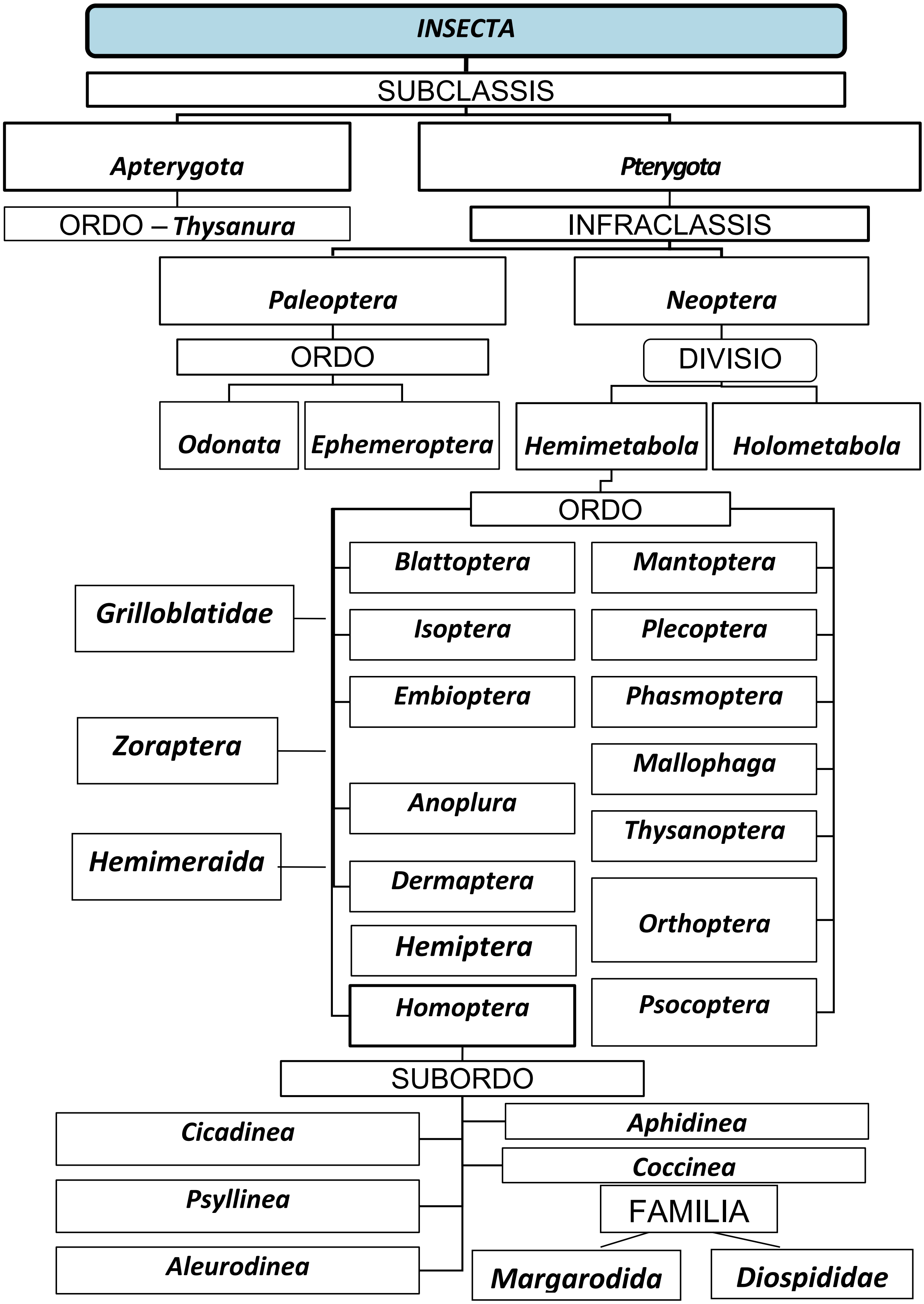
NOMEN-CLATURE		EXAMPLES			
KINGDOM			Animalia		
PHYLUM		Arthropods			34 other phyla
CLASS	Arachnids (spiders, scorpions)		Insects		
ORDER		Hymenoptera	Hemiptera	34 other orders	
FAMILY		Apidae	Lygaeidae		
GENUS		*Apis*	*Oncopeltus*		
SPECIES		*Apis mellifera*	*Oncopeltus fasciatus*		

Supplement G

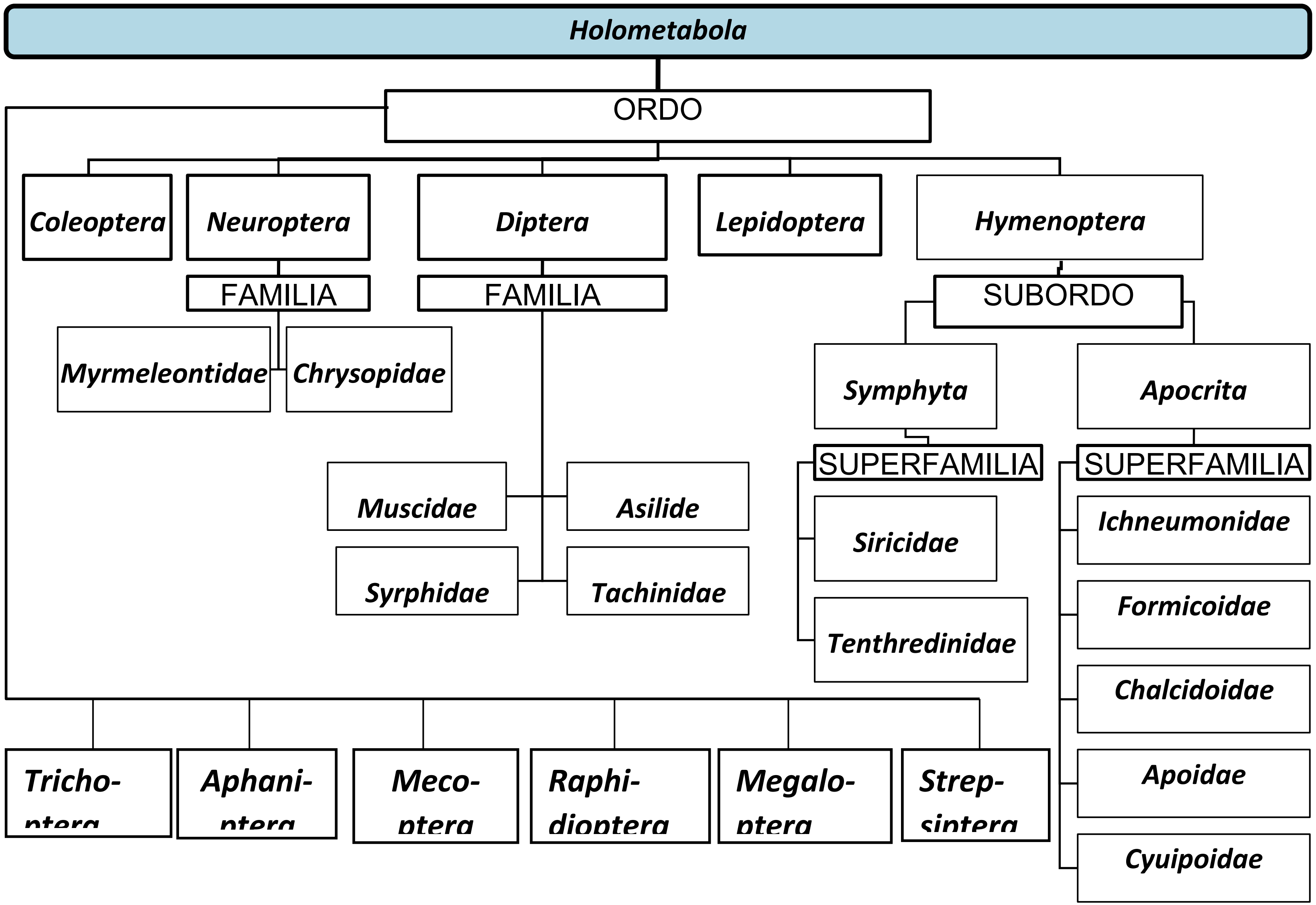
BACTERIA TAXONOMY

NOMENCLATURE	EXAMPLES
DOMAIN	Bacteria
PHYLUM	Firmicutes
CLASS	Bacilli
ORDER	Lactobacillales
FAMILY	Lacpobacillaceae
GENUS	*Lactobacillus*
SPECIES	*Lactobacillus acidophilus*

Supplement H



Supplement H



Supplement I

STAGES OF DEVELOPMENT OF HARMFUL INSECTS, TERMS OF MONITORING AND ASSESSMENT

Conventional designations of development stages in the tables: + – imago; • – eggs; – larva (caterpillar); (-) – their wintering period; ◊ – pupa; E – eonymph; P – pronymph.

- terms of survey, - terms of assessment

Dendrolimus pini

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first									+	+ •	+ •	+ •	•								
										-	-	-	-	-	-	-	-	-	(-)	(-)	(-)
second	(-)	(-)	-	-	-	-	-	-	-												
								◊	◊	◊											
									+	+	+	+									

The wintering place is under the forest floor

Lymantria monacha

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first											+	+	+	+							
											•	•	•	•	•	(-)	(-)	(-)	(-)	(-)	(-)
second	(-)	(-)	-	-	-	-	-	-													
									◊	◊	◊										
											+	+	+	+							

The wintering place is the bark

Panolis flammea

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first		+	+	+	+																
		•	•	•	•																
			-	-	-	-	-	-	-	-	-										
									◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	(◊)	(◊)	(◊)
second	◊	◊	◊																		
		+	+	+	+																

The wintering place is under the forest floor

Bupalus piniarius

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first						+	+	+	+												
							•	•	•	•											
								-	-	-	-	-	-	-	-	-	-				
																◊	◊	◊	(◊)	(◊)	(◊)
second	◊	◊	◊	◊	◊	◊															
						+	+	+	+												

The wintering place is under the forest floor

Diprion pini

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first		+	+	+	+																
		•	•	•	•																
					-	-	-	-	-												
										◊	◊										
											+	+	+								
											•	•	•								
													-	-	-	-	-	-			
																		E	(E)	(E)	(E)
																			(P)	(P)	(P)
second	E P	E P	E P	diapause																	
		◊	◊																		
		+	+	+	+																

The wintering place is under the forest floor

Neodiprion sertiffer

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first														+	+	+	+				
														.	.	.	.	.	(.)	(.)	(.)
second	.	.	.	.																	
				-	-	-	-	-	-	-											
										◊	◊	◊	◊	◊	◊						
														+	+	+	+				

The wintering place are needles

Acantholyda erythrocephala

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first			+	+	+																
			.	.	.																
				-	-	-	-	-													
								E	E	E	E	E	E	E	E	E	E	E	(E)	(E)	(E)
																	P	P	(P)	(P)	(P)
	E	E	E																		
second	P	P	P																		
		◊	◊	◊																	
			+	+	+																

The wintering place is soil

Acantholyda posticalis

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first					+	+	+	+	+												
					.	.	.	.	.												
						-	-	-	-	-											
									E	E	E	E	E	E	E	E	E	E	(E)	(E)	(E)
																	P	P	(P)	(P)	(P)
second	E	E	E	E	diapause																
	P	P	P	P																	
			◊	◊	◊																
					+	+	+	+	+												

The wintering place is soil

Zeiraphera diniana

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first												+	+	+	+	+					
												.	.	.	.	.	.	.	(.)	(.)	(.)
second	.	.	.	.	.																
					-	-	-	-	-	-											
										◊	◊	◊	◊								
												+	+	+	+	+					

The wintering place are shoots

Tortrix viridana

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first								+	+	+											
								.	.	.	.	.	.	.	.	.	.	.	(.)	(.)	(.)
second	.	.	.																		
			-	-	-	-	-														
							◊	◊	◊												
								+	+	+											

The wintering place are shoots

Lymantria dispar

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first										+	+	+	+								
										.	.	.	.	.	.	(-)	(-)	(-)	(-)	(-)	(-)
second	(-)	(-)	(-)																		
			-	-	-	-	-	-	-												
									◊	◊	◊										
										+	+	+	+								

The wintering place is the trunk

Operophtera brumata

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X -III		
first																		+	+	+	
																			(.)	(.)	(.)
second	.	.	.	.																	
			-	-	-	-	-	-													
						◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	+	+	+	

Wintering place - branches

Biston hispidaria, Lycia hirtaria, Erannis defoliaria

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first		+	+																		
		.	.																		
		-	-	-	-	-	-	-													
second	◊	◊ +	◊ +					◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	(◊)	(◊)	(◊)

The wintering place is under the forest floor

Acrocercops brongniardella

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first	(+)	(+)	(+)	+	+	+															
				.	.	.															
					-	-	-	-	-	-											
									◊	◊	◊	◊									
											+	+	+	+	+	+	+	+	(+)	(+)	(+)
second	(+)	(+)	(+)																		

The wintering places are non-residential premises, under the bark of an old trees

Euproctis chrysorroea

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first									+	+	+	+									
									.	.	.	.									
											-	-	-	-	-	-	(-)	(-)	(-)	(-)	(-)
second	(-)	(-)	-	-	-	-	-	-	-												
								◊	◊												
									+	+	+	+									

The wintering place are nests in the crown

Hyphantria cunea

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first				+	+	+	+														
					•	•	•	•	•												
							-	-	-	-	-	-	-								
											◊	◊	◊								
												+	+	+	+						
												•	•	•	•						
													-	-	-	-	-	-			
																		◊	(◊)	(◊)	(◊)
second	◊	◊	◊	◊ +	+	+	+														

The wintering place are bark crack

Leucoma salicis

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first									+	+	+	+									
									•	•	•	•									
										-	-	-	-	-	-	-	-	-	(-)	(-)	(-)
second	-	-	-	-	-	-															
						◊	◊	◊	◊												
									+	+	+	+									

The wintering place is the trunk

Thaumetopoea processionea

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first											+	+	+	+	+						
												•	•	•	•	•	•	•	(•)	(•)	(•)
second	•	•	•																		
			-	-	-	-	-	-	-	-	-										
									◊	◊	◊	◊									
											+	+	+	+	+						

Wintering place are branches

Calliteara pudibunda

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first						+	+	+													
						.	.	.													
								-	-	-	-	-	-	-	-	-	-				
																◊	◊	◊	(◊)	(◊)	(◊)
second	◊	◊	◊	◊	◊	◊															
						+	+	+													

The wintering place is under the forest floor

Malacosoma neustria

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first									+	+	+	+									
									.	.	.	.	.	.	.	.	.	.	(.)	(.)	(.)
second	.	.	.																		
			-	-	-	-	-	-	-												
								◊	◊												
									+	+	+	+									

The wintering place are shoots

Phalera bucephala

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first							+	+	+	+	+	+									
							.	.	.	.	.	.									
								-	-	-	-	-	-	-	-	-	-				
														◊	◊	◊	◊	◊	(◊)	(◊)	(◊)
second	◊	◊	◊	◊	◊	◊															
							+	+	+	+	+	+									

The wintering place is soil

Peridea anceps

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first					+	+	+	+													
					.	.	.	.													
						-	-	-	-	-	-	-									
									◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	(◊)	(◊)	(◊)
second	◊	◊	◊	◊																	
					+	+	+	+													

The wintering place is soil

Exaereta ulmi

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first			+	+	+	+															
				•	•	•															
					-	-	-	-	-												
									◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	(◊)	(◊)	(◊)
second	◊	◊	◊																		
			+	+	+	+															

The wintering place is soil

Alsophila aescularia

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first								+	+	+	+										
									•	•	•	•									
										-	-	-	-	-	-						
																◊	◊	◊	(◊)	(◊)	(◊)
second	◊	◊	◊	◊	◊	◊	◊														
								+	+	+	+										

The wintering place is soil, under the forest floor

Macrophya punctumalbum

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
first					+	+	+	+													
					•	•	•	•													
						-	-	-	-	-	-										
									E	E	E	E	E	E	E	E	E	E	(E)	(E)	(E)
second	E	E	E	E	E	diapause															
			P	P	P																
			◊	◊	◊	◊															
					+	+	+	+													

The wintering place is soil

PESTS OF UNDERGROUND PARTS OF PLANTS
Cockchafer beetles

Year	Stages of development by months and decades																			
	IV			V			VI			VII			VIII			IX			X-III		
	***Melolontha* sp.**																				
first				+	+	+															
					•	•	•														
							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
second	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
third	=	=	=	=	=	=	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡
fourth	≡	≡	≡	≡	≡	≡	≡	≡	≡												
									◊	◊	◊	◊	◊	◊	◊						
															+	+	+	+	+	+	+
fifth	+	+	+	+	+	+															
	Polyphylla fullo																				
first									+	+	+	+									
										•	•	•	•								
											-	-	-	-	-	-	-	-	-	-	-
second	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
third	=	=	=	=	=	=	=	=	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡
fourth	≡	≡	≡	≡	≡	≡	≡	≡	≡												
									◊	◊	◊	◊									
									+	+	+	+									
	Anoxia pilosa																				
first							+	+	+	+											
								•	•	•	•										
									-	-	-	-	-	-	-	-	-	-	-	-	-
second	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
third	=	=	=	=	=	=	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡	≡
fourth	≡	≡	≡	≡	≡	≡	≡	≡	≡												
						◊	◊	◊	◊												
							+	+	+	+											
	Rhizotrogus solstitialis																				
first						+	+	+	+	+	+	+	+								
							•	•	•	•	•	•	•								
							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
second	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
third	=	=	=	=	◊	◊	◊	◊	◊												
						+	+	+	+	+	+	+	+								

	Anomala dubis																				
first							+	+	+	+	+	+									
							•	•	•	•	•	•									
								-	-	-	=	=	=	=	=	=	=	=	=	=	=
second	=	=	=	=	=	=															
						◊	◊	◊	◊	◊	◊										
							+	+	+	+	+	+									

The wintering place is soil

Legend: + (imago); • (eggs); - (first instar larvae); = (second instar larvae); ≡ (third instar larvae); ◊ (pupa)

GRYLLOTALPA GRYLLOTALPA, LETHRUS APTERUS, AGRIOTES LINEATUS, AGROTIS SEGETUM

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
	Gryllotalpa gryllotalpa																				
first					+	+	+	+													
						•	•	•	•												
							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
second	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
third	-	-	-	-	-																
					+	+	+	+													
	Lethrus apterus																				
first			+	+	+	+															
				•	•	•	•														
					-	-	-	-	-	-	-	-									
											◊	◊	◊								
												+	+	+	+	+	+	+	+	+	+
second	+	+	+	+	+	+															
	Agriotes lineatus																				
first					+	+	+	+													
						•	•	•	•												
							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
second	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
third	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
fourth	-	-	-	-	-	-	-	-	-	-	-	-									
												◊	◊	◊	◊	◊	◊	◊	◊	◊	◊
fifth	◊	◊	◊	◊																	
					+	+	+	+													
	Agrotis segetum																				
first						+	+	+													
						•	•	•													
							-	-	-	-	-										
									◊	◊	◊										
										+	+	+									
											•	•	•								
												-	-	-	-	-	-	-	-	-	-
second	-	-	-	-	-																
			◊	◊	◊	◊															
						+	+	+													

The wintering place is soil

PINE SHOOT MOTHS

Year	Stages of development by months and decades																				
	IV			V			VI			VII			VIII			IX			X-III		
	Rhyacionia buoliana																				
first							+	+	+	+											
							.	.	.	.											
								-	-	-	-	-	-	-	-	-	-	-	-	-	-
second	-	-	-	-																	
					◊	◊	◊														
							+	+	+	+											
The wintering place are buds																					
	Rhyacionia duplana																				
first		+	+	+	+																
			.	.	.	.															
				-	-	-	-	-	-	-											
										◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊
second	◊	◊	◊																		
		+	+	+	+																
The wintering place are bark cracks																					
	Blastesthia turionana																				
first				+	+	+	+														
				.	.	.	.														
					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
second	-	-	◊	◊	◊																
				+	+	+	+														
The wintering place are buds																					
	Retinia resinella																				
first					+	+	+														
					.	.	.														
						-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
second	-	-	-	◊	◊																
					+	+	+														
The wintering place are shoots																					

Supplement J

CHECKLIST OF WOODY PLANT INSECTS

Species	Damage
Acanthochermes quercus	
Acanthocinus aedilis	
Acanthocinus carinulatus	
Acanthocinus griseus	
Acantholyda erythrocephala	
Acantholyda stellata	
Acholcus dalmanni	
Achrysocharella ruforum	
Acyrthosiphon caraganae	
Aegeria apiformis	
Aeolesthes sarta	
Agelastica alni	
Ageniaspis fuscicollis	
Agria affinis	
Agrilus angustulus	
Agrilus betuleti	
Agrilus biguttatus	
Agrilus hastulifer	
Agrilus obscuricollis	
Agrilus olivicolor	
Agrilus sulcicollis	
Agrilus viridis	

Continuation of the supplement J

Species	Damage
Agriotes gurgistanus *Agriotes lineatus* *Agriotes obscurus* *Agriotes sputator* *Agrotis segetum* *Agrotis vestigialis* *Agrypon flaveolatum* *Amphimallon solstitialis* *Anastatus disparis* *Andricus foecundatrix* *Andricus inflator* *Anobium domesticum* *Anobium pertinax* *Anomala dubia aenea* *Anomala errans* *Anoxia pilosa* *Anthaxia conradti* *Anthaxia quadripunctata* *Apanteles liparidis* *Apanteles melanoscelus* *Apanteles ordinarius* *Apanteles sericeus* *Apanteles spurius*	

Continuation of the supplement J

Species	Damage
Aphis evonymi	
Aphis fabae	
Aphytis mytilaspidis	
Apocheima hispidaria	
Aradus cinnamomeus	
Archips crataegana	
Archips reticulana	
Archips rosana	
Archips xylosteana	
Arge rosae	
Asemum striatum	
Asterolecanium pustulans	
Asterodiaspis quercicola	
Athous niger	
Barichneumon bilunulatus	
Biorrhiza pallida	
Biston strataria	
Blastesthia turionana	
Blastothrix sericea	
Boarmia bistortata	
Bostrychus capucinus	
Brachyderes incanus	
Bradybatus clentzeri	

Continuation of the supplement J

Species	Damage
Bupalus piniarius	
Calasoma inquisitor	
Cacoecia sycophanta	
Caliroa cinxia	
Callidum violaceum	
Callipogon relictus	
Calliteara pudibunda	
Carpoborus minimus	
Carpocapsa amplana	
Carpocapsa grossana	
Carpocapsa splendana	
Cerambix cerdo	
Cerambix scopolii	
Chionaspis salicis	
Chrysobothris affinis	
Chrysobothris chrysostigma	
Chrysonotomyia ruforum	
Cicindela silvatica	
Cimbex femoratus	
Codiosoma spadix	
Compsilura concinnata	
Cossus cossus	
Cossus terebra	

Continuation of the supplement J

Species	Damage
Cratichneumon nigritarius	
Crosus septentrionalis	
Criocephalus rusticus	
Cryphalus piceus	
Cryptognatha nodiceps	
Curculio glandium	
Curculio nucum	
Cynips quercus calicis	
Cyzenis albicans	
Dahlbominus fuscipennis	
Dasychira albodentata	
Dasyneura laricis	
Dendroctonus micans	
Dendrolimus pini	
Dendrolimus sibiricus	
Dendrolimus superans	
Dioryctria abietella	
Diplolepis quercus-folii	
Diplostichus janithrix	
Diprion hercyniae	
Diprion pini	
Drino inconspicua	
Dryocoetes autographus	

Continuation of the supplement J

Species	Damage
Elateroides dermestoides	
Elateroides flabellicornis	
Ephialtes manifestator	
Erannis defoliaria	
Eremotes porcatus	
Eriosoma ulmi	
Ernestia rudis	
Eucallipterus tiliae	
Euproctis chrysorrhoea	
Eupteromalus nidulans	
Exapate congelatella	
Formica aquilonia	
Formica cinerea imitans	
Formica exsecta	
Formica lugubris	
Formica polyctena	
Formica pratensis	
Formica truncorum	
Galerucella luteola	
Galerucella viburni	
Gilpinia pallida	
Gryllotalpa grullotalpa	
Haltica saliceti	

Continuation of the supplement J

Species	Damage
Hayhurstia tataricae	
Helicomya saliciperda	
Holcocerus arenicola	
Hylesinus crenatus	
Hylesinus eos	
Hylesinus varius	
Hylesinus laticollis	
Hylesinus toranio	
Hylobius abietis	
Hylobius albosparsus	
Hylobius haroldi	
Hylobius pinastri	
Hylotrupes bajalus	
Hylurgops palliatus	
Icerya purchasi	
Ips acuminatus	
Ips duplicatus	
Ips sexdentatus	
Ips subelongatus	
Ips typographus	
Lacon murinus	
Lasiomma baicalense	
Lasiomma infrequens	

Species	*Damage*
Lasiomma laricicola	
Lasiomma melania	
Laspeyresia strobilella	
Lepidosaphes ulmi	
Lethrus apterus	
Leucoma salicis	
Lignyodes enucleator	
Lucanus cervus	
Lycia hirtaria	
Lyctus brunneus	
Lyctus linearis	
Lyctus pubescens	
Lymexylon novale	
Macrophya punctumalbum	
Magdalis frontalis	
Magdalis violacea	
Malacosoma neustria	
Megastigmus strobilobius	
Melanophila acuminate	
Melanophila picta	
Melasoma populi	
Melasoma saliceti	
Melasoma tremulae	

Continuation of the supplement J

Species	Damage
Melolontha hippocastani	
Melolontha melolontha	
Mesites pallidipennis	
Mesoleius tenthredinis	
Mesosa myops	
Meteorus versicolor	
Monochamus galloprovincialis	
Monochamus impluviatus	
Monochamus saltuarius	
Monochamus sutor	
Monochamus urussovi	
Neodiprion sertifer	
Neuroterus numismalis	
Neuroterus quercusbaccarum	
Notodonta anceps	
Lymantria dispar	
Lymantria monacha	
Oecophilla smaragdina	
Olesicampe benefactor	
Opatrum sabulosum	
Oparinia autumnata	
Operophthera brumata	
Orgyia antiqua	

Continuation of the supplement J

Species	Damage
Orthotomicus suturalis	
Oryctes nasicornis	
Ostoma ferrugineum	
Otiorrhynchus niger	
Otiorrhynchus ovatus	
Panolis flammea	
Paranthrene tabaniformis	
Parasarcophaga harpax	
Parnassius mnemosyne	
Parthenolecanium corni	
Pemphigus lactucarius	
Pentodon idiota	
Phaenops cyanea	
Phaenops guttulata	
Phaeogenes invisor	
Phalera bucephala	
Phigalia pedaria	
Phorocera silvestris	
Phyllopertha horticola	
Phyrrhidium sanguineum	
Physokermes piceae	
Pimpla instigator	
Pityogenes chalcographus	

Continuation of the supplement J

Species	Damage
Pityogenes irkutensis	
Pityogenes quadridens	
Pityokteines curvidens	
Pitiophtorus micrographus	
Pissodes harcyniae	
Pissodes notatus	
Pissodes piceae	
Pissodes pini	
Pissodes piniphilus	
Pissodes validirostris	
Plagionotus arcuatus	
Plagionotus detritus	
Pleolophus basizonus	
Poecilonota variolosa	
Poecilopsis pomonaria	
Polygraphus polygraphus	
Polygraphus proximus	
Polyphylla adspersa	
Polyphylla alba	
Polyphylla fullo	
Pristiphora abietinus	
Pristiphora erichsoni	
Pseudaphycus malinus	

Continuation of the supplement J

Species	Damage
Pteleobius kraatzi	
Pteleobius vittatus	
Purpuricenus kaehleri	
Quadraspidiotus perniciosus	
Retinia resinella	
Rhabdophaga rosaria	
Rhabdophaga salicis	
Rhagium inquisitor	
Rhagium mordax	
Rhagium sycophanta	
Rhaphidia ophiopsis	
Rhisophagus grandis	
Rhizotrogus aequinoctialis	
Rhizotrogus aestivus	
Rhyacionia buoliana	
Rhyacionia duplana	
Rhyncolus culinaris	
Rhyssa persuasoria	
Rodolia cordinalis	
Ropalicus tutela	
Roptocerus xylophagorum	
Sacchiphantes abietis	
Sacchiphantes viridis	

Species	Damage
Saperda carcharias	
Saperda populnea	
Saperda scalaris	
Scolytus amurensis	
Scolytus intricatus	
Scolytus kirschi	
Scolytus morawitzi	
Scolytus multistriatus	
Scolytus pygmaeus	
Scolytus ratzeburgi	
Scolytus rugulosus	
Scolytus sulcifrons	
Scolytus zaitzevi	
Selatosomus aeneus	
Selatosomus latus	
Siphonaphis padi	
Sirex ermak	
Sirex juvencus	
Sirex noctilio	
Spondylis buprestoides	
Stromatium unicolor	
Strophosomus capitatus	
Strophosomus rufipes	

Continuation of the supplement J

Species	Damage
Sturmia scutellata	
Symydobius oblongus	
Telenomus gracilis	
Telenomus laeviuscus	
Telenomus verticillatus	
Tetraneura ulmi	
Tetropium castaneum	
Tetraneura gabrieli	
Tetraneura gracilicorne	
Tetraneura fuscum	
Tetraneura staudingeri	
Thecodiplosis brachyptera	
Tomicobia seitneri	
Tomicus minor	
Tomicus piniperda	
Tortrix viridana	
Tremex fuscicornis	
Trichogramma embryophagum	
Trichogramma evanescens	
Trichogramma pallida	
Trypodendron lineatum	
Trypodendron signatum	
Urocerus gigas	

Continuation of the supplement J

Species	Damage
Vanessa antiopa *Vespa crabro* *Xeris spectrum* *Xiphydria camelus* *Xiphydria longicollis* *Xyleborinus saxeseni* *Xyleborus dispar* *Xylechinus pilosus* *Xylogenes dilatatus* *Xylonites retusa* *Xylotrechus antilope* *Xylotrechus altaicus* *Xylotrechus rusticus* *Zeiraphera diniana* *Zeuzera pyrina*	

Supplement K

CHECKLIST OF WOODY PLANT DISEASES (pathogens)

Species	Damage
Abortiporus borealis	
Agrobacterium tumefaciens	
Albugo candida	
Alternaria humicola	
Amyloporia xantha	
Apiosporium piniphilum	
Apiosporium salicinum	
Antrodia serialis	
Antrodia sinuosa	
Antrodia vaillantii	
Antrodia xantha	
Arceuthobium oxycedri	
Armillaria mellea	
Armillaria ostoyae	
Armillaria borealis	
Ascocalyx abietina	
Aspergillus glaucus	
Aspergillus niger	
Biatorella difformis	
Biatoridina pinastri	
Bjerkandera adusta	
Botrytis cinerea	

Species	Damage
Brunchorstia pinea	
Bursaphelenchus xylophilus	
Cenangium abietis	
Cercospora acerina	
Cercospora microsora	
Ceratocystis fagacearum	
Ceratocystis roboris	
Ceratocystis ulmi	
Ceratocystis valachicum	
Chaetomium globosum	
Chrysomyxa abietis	
Chrysomyxa ledi	
Chrysomyxa pirolae	
Cladosporium herbarum	
Climacocystis borealis	
Clithris quercina	
Coccomyces hiemalis	
Coleosporium campanulae	
Coleosporium senecionis	
Coleosporium sonchi-arvensis	
Coleosporium tussilaginus	
Coniophora puteana	
Coleosporium cerebella	

Continuation of the supplement K

Species	Damage
Coriolellus serialis *Coriolopsis trogii* *Coriolus vaporarius* *Coriolus versicolor* *Coriolus zonatus* *Corticium leave* *Cronartium flaccidum* *Cronartium ribicola* *Cryptodiaporthe populea* *Cuscuta europaea* *Cuscuta monogyna* *Cytophoma pulchella* *Cylindrosporium hiemale* *Cytospora chrysosperma* *Cytospora foetida* *Cytospora intermedia* *Cytospora leucostoma* *Cytospora quercella* *Daedalea quercina* *Dasyscyphus willkommii* *Diaporthe perniciosa* *Diatrype stigma* *Discoccum asperum*	

Species	Damage
Discula bruneo-tingens	
Dothichiza ferruginosa	
Dothichiza populea	
Dothidella betulina	
Dothidella ulmi	
Endomyces magnusii	
Endomycopsis vernales	
Endothia parasitica	
Endoxylina astroidea	
Erwinia nimipressuralis	
Erwinia salicis	
Fibuloporia vaillantii	
Fistulina hepatica	
Flammulina velutipes	
Fomes fomentarius	
Fomitopsis annosa	
Fomitopsis officinalis	
Fomitopsis pinicola	
Fomitopsis rosea	
Fumago vagans	
Funalia trogii	
Fusarium bulgigenum	
Fusarium oxysporum	

Species	Damage
Fusarium roseum *Fusarium sporotrichoides* *Fusicladium betulinum* *Fusicladium saliciperdum* *Ganoderma applanatum* *Ganoderma lipsiene* *Gloeophyllum sepiarium* *Gloeophyllum odoratum* *Gloeosporium betulinum* *Gloeosporium quercinum* *Gloeosporium tremulae* *Gnomonia quercina* *Graphium ulmi* *Gremmeniella abietina* *Grumenula abietina* *Guignardia aesculi* *Gymnosporangium juniperum* *Hendersonia acicula* *Herpotrichia nigra* *Herpotrichia juniperi* *Heterobasidion annosum* *Heterobasidion parviporum* *Heterobasidion abietinum*	

Continuation of the supplement K

Species	Damage
Hirschioporus abietinus *Hirschioporus fusco-violaceus* *Hormiscium pinophilum* *Hypodermella sulcigena* *Hypoxylon pruinatum* *Hysterographium fraxini* *Inonotus dryadeus* *Inonotus dryophilus* *Inonotus hispidus* *Inonotus obliquus* *Ischnoderma benzoinum* *Kuehneromyces mutabilis* *Lachnellula willkommii* *Laetiporus sulphureus* *Lentinus lepideus* *Lenzites betulina* *Libertella fraxini* *Lophodermium abietis* *Lophodermium conigenum* *Lophodermium macrosporum* *Lophodermium pinastri* *Lophodermium seditiosum* *Lophodermium juniperinum*	

Continuation of the supplement K

Species	Damage
Loranthus europaeus	
Marssonina betulae	
Marssonina populi	
Massaria inguinans	
Melampsora alli-populina	
Melampsora evonymi-caprearum	
Melampsora larici-caprearum	
Melampsora larici-populina	
Melampsora larici-tremulae	
Melampsora larici-salicina	
Melampsora pinitorqua	
Melampsora ribesii-vinimalis	
Melampsorella cerastii	
Melampsoridium betulinum	
Melanconium botulinum	
Meria laricis	
Microsphaera alphitoides	
Microsphaera betulae	
Microsphaera berberides	
Microsphaera grossulariae	
Microsphaera lonicera	
Microsphaera penicillata	

Continuation of the supplement K

Species	Damage
Microsphaera syringae *Microsphaera vanbruntiana* *Microsphaera viburni* *Mucor mucedo* *Mucor racemosus* *Monilia sitophila* *Mycosphaerella ribis* *Naemospora croceola* *Nectria cinnabarina* *Nectria coccinea* *Nectria ditisima* *Nectria galligena* *Nummularia buillardii* *Onnia triqueter* *Osmoporus odoratus* *Oxyporus populinus* *Paxillus panuoides* *Penicillium commune* *Peniophora gigantean* *Peridermium pini* *Pestalotia hartigii* *Phacidium infestans* *Phaeolus schweinitzii*	

Continuation of the supplement K

Species	Damage
Phialophora fastigata	
Phellinus chrysoloma	
Phellinus igniarius	
Phellinus hartigii	
Phellinus pini	
Phellinus robustus	
Phellinus tremulae	
Phlebiopsis gigantea	
Pholiota adiposa	
Pholiota squarrosa	
Phomopsis quercella	
Phragmidium disciforum	
Phyllactinia suffulta	
Phyllosticta fraxini	
Phyllosticta sphaeropsoidae	
Phytophthora cactorum	
Phytophthora infestans	
Piptoporus betulinus	
Plasmopara viticola	
Pleurotus ostreatus	
Podosphaera oxyacanthae	
Pollacia elegans	
Pollacia radiosa	

Continuation of the supplement K

Species	Damage
Polyporus squamosus	
Polystictus circinatus	
Pseudomonas fluorescens	
Pseudomonas fraxini	
Pseudomonas quercus	
Pseudomonas quercina	
Pseudomonas pini	
Pseudomonas piri	
Pseudomonas remifaciens	
Pseudomonas syringae	
Pullularia pullulans	
Puccinia graminis	
Pythium debaryanum	
Rhizoctonia solani	
Rhizopus nigricans	
Rhizosphaera kalkhoffii	
Rhytisma acerinum	
Rhytisma pseudoplatanus	
Rhytisma punctatum	
Rhytisma salicinum	
Rosselinia quercina	
Sclerophoma pithyophila	
Sclerotinia alni	

Continuation of the supplement K

Species	Damage
Sclerotinia aucupariae	
Sclerotinia betulae	
Sclerotinia graminearum	
Scleroderris lagerbergii	
Schizophyllum commune	
Septoria quercina	
Septoria ribis	
Serpula lacrymans	
Sphaeropsis malorum	
Sphaerotheca pannosa	
Stereum abietinum	
Stereum frustulosum	
Stereum hirsutum	
Stereum sanguinolentum	
Stigmina compacta	
Stromatinia pseudotuberosa	
Sydowia polyspora	
Synchytrium endobioticum	
Taphrina acerina	
Taphrina alni-incanae	
Taphrina aurea	
Taphrina betulae	
Taphrina carnea	

Continuation of the supplement K

Species	Damage
Taphrina cerasi *Taphrina epiphylla* *Taphrina johansonii* *Taphrina pruni* *Taphrina rhisophorus* *Taphrina turgida* *Taphrina tosguinetii* *Tilletia caries* *Thamnidium elegans* *Thecopsora areolate* *Thecopsora padi* *Thelephora terrestris* *Thyrostroma compactum* *Trichaptum abietinum* *Trichaptum fusco-violaceum* *Trichocladia caraganae* *Trichaptum enonymi* *Trichoderma lignorum* *Trichothecium roseum* *Tubercularia vulgaris* *Typhula graminearum* *Uncinula aceris* *Uncinula salicis*	

Continuation of the supplement K

Species	Damage
Uncinula fraxini	
Uncinula clandestine	
Ustilago nuda	
Ustilago tritici	
Valsa sordida	
Venturia chlorospora	
Venturia ditricha	
Venturia populina	
Venturia tremulae	
Verticillium albo-atrum	
Verticillium dahliae	
Verticillium glaucum	
Verticillium latericium	
Viscum album	
Vuilleminia comedens	

VOCABULARY

NOUNS

Abundance – чисельність, рясність, поширеність, багатство

Accuracy – точність

Acorn – жолудь

Adult – доросла комаха (імаго)

Aphid – попелиця

Arachnids – павукоподібні

Assessment – оцінювання

Bacterium (bacteria) – бактерія

Bait – наживка, принада

Bark – кора

Bast – луб

Beetle – жук

Benefit – користь

Blossom – цвіт, квітка, суцвіття

Borer – точильник

Branch – гілка

Brushwood – хмиз, чагарник

Bud – бутон, брунька

Bug – клоп

Bulb – цибулина

Burl, wart – кап

Burn – опік

Canopy – намет

Cause – чинник, причина

Cell – клітина

Cockchafer – хрущ

Chemicals – хімічні речовини

Cockroach – тарган

Cocoon – кокон

Cohort – покоління, генерація

Compaction – ущільнення

Cone – шишка

Consequence – наслідок

Core – ядро

Cricket – цвіркун

Curliness – кучерявість

Curvature – кривизна, викривлення

Damage – пошкодження

Deforestation – вирубання лісів

Deformation – деформація, викрилення

Degree – ступінь

Depletion – виснаження

Desert – пустеля

Destruction, disturbance – порушення

Deterioration – погіршення стану

Development – розвиток

Dioecious – дводомні рослини

Disease – хвороба

Disorder – захворювання, розлад

Dispersal – розсіювання

Disturbance – порушення

Diversity – різноманіття

Division – поділ

Drought – посуха

Egg – яйце

Emergence – поява

Enemy – ворог

Enterprise – підприємство

Entomologist – ентомолог

Environment – навколишнє середовище

Enzyme – фермент

Establishment – поновлення

Estimation, evaluation – оцінювання

Examination – обстеження

Excavation – розкопки

Fade – цвіль

Feature – особливість

Female – самиця

Firewood – дрова

Flea – блоха

Focus (pl. Foci) – осередок (осередки)

Forecast – прогноз

Fungus (pl. fungi) – гриб (гриби)

Gall – гал

Generation – покоління, генерація

Germination – схожість

Grove – гай, порослевий ліс

Gum – смола, камедь

Habitat – середовище існування

Harmfulness – шкідливість

Heartwood – серцевина

Hole – отвір

Hollow – дупло

Host – живитель

Hothouse, greenhous – теплиця

Humidity – вологість

Imago – доросла комаха (імаго)

Impact – вплив

Incidence – трапляння (хвороби)

Increment – приріст

Index (pl. indices) – індикатор (індикатори)

Influence – вплив

Insect – комаха

Inspection – обстеження

Intensity – інтенсивність

Interaction – взаємодія

Invertebrate – безхребетне

Knot – сучок

Landowner – землевласник

Larch – модрина

Larva (pl. larvae) – личинка (личинки)

Layer – ярус

Leafroller – листовійка

Lesion – ураження

Limb – сучок

Limbing – обрізка сучків

Log – колода

Logging – лісозаготівля

Loss (pl. losses) – втрата (збитки)

Louse (pl. lice) – воші

Lumber – пиломатеріали

Lure – приманка

Male – самець

Mammal – ссавець

Mean (pl. means) – засіб (засоби)

Measure (pl. measures) – захід (заходи)

Mensuration – таксація

Mildew – пліснява, цвіль

Mistletoe – омела

Mite – кліщ

Mold – пліснява

Mollusk – молюск

Molt – линька, линяння

Monoecious – однодомні рослини

Moss – мох

Moth – метелик, міль

Mucus – слиз

Mulch – мульча

Mummification – муміфікація

Needle (pl. needles) – голка (хвоя)

Nematode **–** нематода

Nest – гніздо

Noctuid – совка, нічниця

Nucleus – ядро

Nutrient – поживна речовина

Nymph – німфа

Observation – спостереження

Offspring – потомство

Order – ряд (у систематиці)

Origin – походження, першопричина

Outbreak – спалах

Outgrowth – наріст, паросток

Parasite – паразит

Parasitoid – паразитоїд

Path – стежка

Pathogen – патоген

Pest - шкідник

Petal – пелюстка

Phenomena – явище

Pheromone – феромон

***Plaque* –** наліт

Poison – отрута

Pole – жердина

Pollinator – запилювач

Poplar – тополя

Predator – хижак

Prediction – прогноз, прогнозування

Preventing – запобігання

Prey – здобич, жертва

Pruning – обрізка

Psyllid – листоблошка

Pupa (pl. pupae) – лялечка (лялечки)

Pustule – пустула

Quotient – коефіцієнт, частка

Radicle – корінець

Rate – темп, розмір, частка

Reforestation – лісовідновлення

Regeneration – генерація, покоління, відновлення

Reserve – заповідник

Resistance – стійкість (напр. до патогенів)

Ride, path – просіка

Rodent – гризун

Root – корінь

Rot – гниль

Route survey – маршрутне обстеження

Representative – представник

Rust – іржа

Sample – зразок, вибірка

Sapling – саджанець

Sapwood – заболонь

Sawfly – пильщик

Sawlog – пиловник

Seedling – сіянець

Set – комплекс

Severity – інтенсивність

Shape – форма, вигляд

Shoot – пагін

Shrub, bush – кущ

Sign – ознака

Silviculture – лісівництво

Slim – слиз

Slope – схил

Slug – слимак

Snail – равлик

Spore – спора

Sprig – гілочка, пагін

Sprout – пагін, паросток

Stem – стебло, стовбур

Sting – жало

Storey – ярус

Strain – штам

Stump, stub – пень

Survey – нагляд

Suvel – сувель

Symptom – симптом

Tapping – підсочка

Tar – смола

Tending – догляд

Thinning – рубка (догляду)

Thorn – шип, колючка

Threat – загроза, небезпека

Thrips – тріпс

Tier – ярус

Tissue – тканина

Toolbox – набір інструментів, інструментарій

Trail – слід, стежка

Trap – пастка

Trunk – стовбур

Tumor – пухлина

Twig – гілочка

Ulcer – виразка

Underbrush, underwood, undergrowth – підлісок

Unearthing – розкопки

Vegetation – рослинність

Vermin – паразити

Vertebrate – хребетне

Viability – життєздатність

Violation – порушення

Virgin forest – праліс

Wasp – оса, перетинчастокриле

Weakening – ослаблення

Weed – бур'ян

Weevil – довгоносик

Whorl – мутовка, кільце

Windbreak – бурелом

Windblow, windthrow – вітровал

Wireworm – дротяник

Withering – в’янення

Wound – рана

Yeast – дріжджі

VERBS

Assess – оцінювати

Avoid – уникати

Benefit – допомагати, надавати користь

***Blossom* –** цвісти

Bring about – призводити, викликати

Carry out – здійснювати

Cause – чинити, викликати

Chew – жувати

Compete – конкурувати

Conduct – провадити, вести,

Contribute – сприяти

Control – контролювати, регулювати

Crawl – повзати

Damage – шкодити, пошкоджувати

Defend – захищати

Destroy – знищувати

Destruct – руйнувати

Deteriorate – погіршувати

Determine – визначати

Dieback – відмирати

Disperse – розсівати

Disrupt – порушувати

Draw – окреслювати

Dry up – сохнути

Eliminate – усувати, ліквідувати

Embrace – охоплювати

Estimate – оцінювати

Fade – в’янути

Forecast – прогнозувати

Germinate – проростати

Harm – шкодити

Hatch – вилуплюватися

Highlight – висвітлювати, виділяти

Identify – розпізнавати, визначати

Impair –погіршувати

Increase –збільшувати

Infect – заражати

Inhabit – населяти, мешкати

Interact – взаємодіяти

Justify – обґрунтовувати

Lead – призводити

Mate – паруватися

Measure – міряти

Monitor – контролювати

Observe – спостерігати

Obtain – отримувати, добувати

Overwinter – зимувати

Penetrate – проникати

Pollinate – запилювати

Predict – прогнозувати

Prevent – запобігати

Promote – сприяти

Prove – доводити

Provide – забезпечувати

Prune – обрізати, скорочувати

Pursue – переслідувати, займатися

Quantify – кількісно оцінювати

Rate – оцінювати

Reduce – зменшувати

Resist – протидіяти, чинити опір

Rot – гнити

Spoil – псувати

Sporulate – спороносити

Spread – поширюватись

Sting – жалити

Suck – смоктати

Suffer – потерпати, страждати

Survey – інспектувати, наглядати

Tend – доглядати

Trap – ловити в пастку

Undertake – здійснювати

Unearth – розкопувати

Wipe out – знищувати

Wither – в'янути

ADJECTIVES

Adverse – несприятливий, шкідливий

Available – доступний, придатний, досяжний

Beneficial – корисний

Burnt – сгорівший, обгорівший

Damp – вологий

Desirable – бажаний

Developed – розвинений

Diverse – різноманітний

Dry – сухий

Efficient – ефективний

Essential – суттєвий

Gnarled – сучкуватий

Harmful – шкідливий

Harmless – нешкідливий

Herbaceous – трав’янистий

Homogeneous – однорідний

Legal – законний, правовий

Light-demanding – світлолюбний

Meadow – лучний

Nocturnal – нічний (спосіб життя)

Perennial – багаторічний

Profound – глибокий

Relevant – актуальний

Resistant – стійкий

Ripe – стиглий, зрілий

Rotten – гнилий, трухлявий

Sexual – статевий

Shade-requiring – тіньолюбний

Spinate, thorny – колючий

Stagnant – в'ялий, застійний

Sticky – липкий

Undemanding – невибагливий

Underdeveloped – недорозвинений

Understocked – низькоповнотний

Undesirable – небажаний

Unfavorable – несприятливий

Uniform – однорідний

Unwanted – небажаний

Uppressed – пригнічений

Withered – зів'ялий

COLLOCATIONS

Active substance – діюча речовина

Advisable to apply – доцільно застосувати

Affected surface – уражена поверхня

Affected trees – уражені дерева

Annual temperature – річна температура

Artificial plantation – штучне насадження

Artificial regeneration – штучне лісовідновленя

Assimilation apparatus – асиміляційний апарат

Average daily temperature – середня добова температура

Average height and diameter – середня висота і діаметр

Bark beetle – короїд

Bark beetle gallery – хід короїда

Basal area – сума площ поперечного перерізу

Based upon the obtained results – на основі отриманих результатів

Biometric indicators – лісівничо-таксаційні показники

Bird of prey – хижий птах

Blister rust – пухирчаста іржа

Bracket fungi – трутовик

Broad-leaved forest – широколистяний ліс

Clear cutting – суцільна рубка

Carry out the research – проводити дослідження

Conifer tree – хвойне дерево

Coppice restoration – вегетативне поновлення

Crown coverage percentage – зімкненість крони

Crown fire – верхова пожежа

Curling leaves – кучерявість листя

Current state – сучасний стан

Dead trees – відпад

Dead wood – сухостій

Decayed wood – гнила деревина

Deciduous tree – лиственное дерево

Division stage – стадія ділення

DNA (deoxyribonucleic acid) – ДНК

Dormant bud – спляча брунька

Dormant stage – стадія спокою

Due to abovementioned facts – внаслідок вище-викладених фактів

Eaten fruits – виїдені плоди

Edge of forest – узлісся

Egg stage, egg laying – період відкладання яєць

Even aged – одновікові (одноярусні)

Experience gained – набутий досвід

Experimental data – дослідні дані

Felling area, cutting unit – лісосіка, зруб

Fertile soil – родючий ґрунт

Foliage-browsing insects – комахи-хвоєлистогризи

Forecast to assess – прогноз для оцінки

Forest belt – лісосмуга

Forest coverage – лісистість

Forest floor (forest litter) – лісова підстилка

Forest fuels – лісові горючі матеріали

Forest mensuration – вимірювання лісу

Forest nursery – лісовий розсадник

Forest pathology examination (inspection) – лісопатологічне обстеження

Forest plantations – лісові культури

Forest residues (logging residues) – порубкові рештки

Forest stand, timber stand – деревостан

Forest site conditions – тип лісорослинних умов

Forest type – тип лісу

Forest use – лісокористування

Fresh forest types – свіжі умови лісу

Frost crack – морозобійна тріщина

Further computations – подальші розрахунки

Gall wasp, gallfly – горіхотвірка

General conclusions and proposals – загальні висновки та пропозиції

General population – генеральна сукупність

Ground vegetation – надґрунтовий покрив

Groundwater level – рівень ґрунтових вод

Growing season – вегетаційний період

Growing stock – запас

Hardwood trees – листяні дерева

High accuracy – висока точність

High forest – насадження насіннєвого походження

Incipient stage – початкова стадія

Index class scale after Prof. M. M. Orlov – бонітетні шкали проф. Орлова

Knotty wood – сучкувата деревина

Land temperature – температура ґрунту

Larval gallery – хід личинки ксилофага

Larval tunnel – хід личинки мінера листя

Lay eggs – відкладати яйця

Leafroller – листовійка

Leaf spot – плямистість

Leaf unfolding – розпускання листя

Litterfall (plant litter, leaf litter, tree litter, soil litter) – опад, лілсова підстилка

Live biomass – фітомаса

Living ground cover – живий надґрунтовий покрив

Local executive bodies – місцеві органи влади

Local governments – органи місцевого самоврядування

Low forest (coppice) – насадження вегетативного походження

Mathematical computations – математичні обчислення (розрахунки)

Mature stage – стадія зрілості

Mean age – середній вік

Mensurational indices – таксаційні показники

Mensurational tables – лісотаксаційні таблиці

Mixed stand – мішані деревостани

Modern science – сучасна наука

Mole cricket – вовчок звичайний, капустянка

Natural regeneration – природне поновлення, підріст

Nature reserve – заповідник

Nuptial chamber – шлюбна камера

Nutritive substance – поживна речовина

Open wood – рідколісся

Overmature stand – перестійний деревостан

Owing to this – завдяки цьому

Pathoentomological survey – патоентомологічний нагляд.

Phytosanitary condition – фітосанітарний стан

Poisonous substances – отруйні речовини

Potential threat – потенційна загроза

Powdery mildew – борошниста роса

Primeval forest – первісний ліс.

Protective measures – захисні заходи

Pure stand – чисті деревостани

Quantitative assessment – кількісне оцінювання

Recreational pressure – рекреаційне навантаження

Regeneration harvest – лісозаготівля, рубки головного користування

Regeneration tending – лісівничий догляд

Relative density of stocking – повнота

Relevance of study – актуальність досліджень

Reproductive stage – репродуктивна стадія

Research data – дослідні дані

Resin duct – смоляні ходи

Rest stage – стадія спокою

Ripe wood – стигла деревина

RNA (ribonucleic acid) – РНК

Root cause (prime cause) – першопричина

Root collar – коренева шийка

Root rot – коренева губка

Sampling plot – пробна площа

Silvicultural and mensurational characteristics – лісівничо-таксаційні характеристики

Single celled – одноклітинний

Site index – бонітет

Site index class – клас бонітету

Spring frosts – весняні заморозки

Statistical description – статистичний опис

Suggestions for forest practice – пропозиції виробництву

Surface fire – низова пожежа

Sustainable forestry – стійке лісове господарство

Temperature threshold – температурний поріг

Temporary sample plots – тимчасові пробні площі

Timely planning – своєчасне планування

Transitory stage – перехідна стадія

Tree cover – зімкненість

Two-aged stand – двоярусний деревостан

Underground fire – підземна пожежа

Uneven aged – різновікові

Urban forests – міські ліси

Urgent issues – нагальні питання

Urgent problems of contemporaniety – нагальні проблеми сучасності

Vascular mycosis – судинний мікоз

Vector of disease – переносник захворювань

Wild stand – корінний деревостан

Winter survival – зимостійкість

Witch's broom – відьмина мітла

Wood waste – відходи деревини

Yield of commercial wood – вихід ділової деревини

Yield tables – таблиці ходу росту

Young stage – ювенільна фаза