MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
BILA TSERKVA NATIONAL AGRARIAN UNIVERSITY

Faculty of Agrobiotechnology

Department of Forestry

FOREST BREEDING

Methodical instructions

for practical and self-study for applicants
of first (bachelor's) level of higher education
speciality 205 «Forestry»

Bila Tserkva
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Forest breeding: Methodical instructions for practical and self-study for applicants of first (bachelor's) level of higher education speciality 205 «Forestry». T.P. Lozinska, S.M. Levandovska, V.S. Khakhula, M.V. Lozinskyi, A.I. Yurchenko. Bila Tserkva, 2025. 100 p.

The guidelines are written to develop the knowledge and practical skills necessary to perform practical tasks in forest breeding.

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INTRODUCTION

Increasing forest productivity and improving forest quality are the most important tasks of the national forestry sector. To solve these problems, it is necessary to use the achievements of science and all the tools available to forestry.

The main ones are the knowledge of the impact on the environment in which forest plantations exist, as well as the impact on the forest plantations themselves, namely improving its composition, using more rational means of growing and developing forest crops, reducing the recovery period, improving the sanitary condition, etc. All these measures can not only increase the overall productivity of plantations, but also improve the natural composition of plantations. In this context, tree breeding is of particular importance, as it is designed to improve existing species and increase their productive and adaptive potential.

The use of breeding methods to improve forest tree species is aimed at transforming forestry into a profitable industry that is able to maintain forest plantations, create new ones, and serve the needs of gardening, which is becoming more extensive every day.

Forest breeding is one of the youngest branches of forestry. Intensive development and implementation of its elements in production requires training of a large number of highly qualified personnel. Therefore, in an effort to improve the practical training of students and improve the educational process, the authors, based on their experience of teaching the course ‘Forest Breeding’ at the Department of Forestry, created these guidelines. They are designed in such a way that while working on assignments, students master the basic techniques of breeding work, as well as consolidate in practice the knowledge they have gained during the study of the theoretical course.

The purpose of studying the discipline «Forest Breeding» is to develop theoretical knowledge and practical skills of the laws of heredity and variability of woody plants and use them in forestry practice to increase their productivity, resistance to diseases, pests and adverse environmental conditions, as well as to preserve and restore forest genetic resources.

Objectives of the discipline:

1. Introduction to the basic principles and methods of forest species breeding (study of modern achievements in the field of genetics and **breeding** of forest plants; analysis of the genetic diversity of forest ecosystems).
2. Study of methods for assessing the genetic value of forest trees (development and use of criteria for evaluating forest species for breeding; conducting field and laboratory research).
3. Mastering the technologies for creating breeding plantations (establishment of experimental plantations, cultivation of highly productive planting material).
4. Conservation of forest genetic resources (development of strategies for the conservation of rare and valuable forest species).
5. Implementation of breeding achievements in forestry (assessment of the economic efficiency of implementing breeding innovations; development of recommendations for practical use).

The discipline «Forest Breeding» is aimed at ensuring the efficient use of forest genetic resources and promoting sustainable management of forest ecosystems.

As a result of studying the discipline, students must develop certain competencies and expected learning outcomes.

IC. Ability to solve complex problems of research and/or

GC.7. Knowledge and understanding of the subject area and understanding of the profession.

GC.8. Ability to apply knowledge in practical situations.

GC.9. Ability to learn and master modern knowledge.

GC.10. The desire to preserve the environment.

GC 12. Ability to search, process and analyse information from various sources.

PC 2. Ability to conduct forestry measurements and research.

PC 5. Ability to solve the tasks of creating plantations, their cultivation and formation based on the study of literary and regulatory sources of best practices.

PC 9. Ability to develop project documentation, including descriptions, regulations, instructions and other documents.

PC 12. Environmental thinking and awareness, attitude to nature as a unique value that provides living conditions for humanity, personal responsibility for the state of the environment at the local, regional, national and global levels.

EXPECTED LEARNING OUTCOMES

Symbol of learning outcomes in the speciality «Forestry» in accordance with the study programme	Learning outcomes for the discipline
PRS 4. Possess basic humanitarian, natural science and professional knowledge to solve problems in the organisation and management of forestry.	RS 4.1 Know the biological mechanisms of transmission of hereditary traits;
	RS 4.2. To know the methods of obtaining source material: hybridisation, mutagenesis, polyploidy and haploidy, vegetative propagation;
	RS 4.3. To know the methods of inventory of forest plantations for the purpose of positive selection;
	RS 4.4. To know the methods of optimising the genetic structure of plantations based on plus and population selection;
	RS 4.5. Know the system of seed production of individual forest crops
PRS 5. Understand and apply the peculiarities of the processes of growth and development of forest plantations, theories and principles of forestry to solve professional problems.	RS 5.1. Be able to use in practice the methods of selection and propagation of forest crops;

Thus, the methodological recommendations for practical work in the discipline «Forest Breeding» are aimed at providing students with knowledge of the theoretical foundations of the subject, as well as the application of the acquired knowledge, skills and abilities in practice.

PRACTICAL WORK NO. 1

Topic: **FORM DIVERSITY OF THE MAIN FOREST-FORMING SPECIES**

Aims: to learn how to identify the form diversity of tree species and analyse their variability and heredity in natural conditions.

Materials and equipment: herbarium specimens, samples of wood, bark, cones, fruits and seeds, drawings, photographs of trees as a whole and their parts.

Trees and shrubs, like all living organisms, are characterised by considerable variability. Each plant species that occupies a specific habitat, with certain conditions of existence, is characterised by a variety of forms. The emergence of various forms in tree species is associated with the habitat, which affects the course of plant development and depends on the phylogenetic history of the species.

If the range of a species is large and there are significant differences in climatic conditions in different parts of it, then the species has so-called climatic or geographical forms and varieties. If a species is found in different soil conditions, edaphic forms are formed. Different responses of plants to certain climatic, edaphic or biotic factors can lead to the emergence of morphological, physiological and phenological forms of a particular breed.

As a result of natural selection, those forms that prove to be the most viable are consolidated and further developed. The diversity of tree species makes it possible to select among them, distinguishing from the total number of those forms, varieties or types that are superior to others in any respect.

Through systematic selection, a useful trait can be enhanced over a number of generations. In any forest plantation, in forest crops, in nurseries, you can find a significant form diversity of forest species. However, in some cases, we can observe sharply defined forms and varieties of plants, while in others, the forms are not so sharply defined, and to identify them, a «sharp» eye, good observation and some experience are required. Since form diversity is the main material for primary breeding work, it is necessary to have some experience in studying species and at the same time familiarising yourself with the main forestry species existing in nature. When studying forms and varieties of tree species, it is important for breeders to establish their economic and silvicultural value.

Task 1. Get acquainted with the progress of work on identifying the form diversity of tree species, features and requirements for this work.

When describing the crown of trees, pay attention not only to the shape, but also to the placement of branches of different orders in relation to each other and to the stem, describe the angle, directions of the ends of the shoots, direction of the branching plane, etc.

When describing the bark, remember that bark characteristics change with the age of the tree and its location on the tree.

When describing morphological features, it is advisable to do so in conjunction with other features, so that you can identify the combined occurrence of certain features and their cohesion.

Task 2. Identify the main features of species diversity and peculiarities of their description in Scots Pine (*Pinus silvestris L.*).

Scots pine (Pinus silvestris L.). Pine is characterised by considerable morphological variability and the presence of edaphic forms and varieties.

Variability of reproductive organs: usually the anthers of male inflorescences are yellow, but there are specimens of pines with reddish anthers.

There are forms that differ in cones. They have either flat or convex shields and vary in the shape of the apophysis (a rhombic area at the thickened end of the seed scales of a pine cone) – sharp, blunt, hooked or needle-shaped. There is a significant difference in the size of mature cones (from very small to large). The size and colour of the seeds varies (light grey, dark, variegated). You can find such forms of pines that differ in the number of cones on the shoot – from one or two to a very large number. Researchers have discovered a form that can be called multi-cone, fruiting shoots of this form seem to be «covered» with numerous cones that form whole clusters.

Noticeable differences are observed in pines in the rate of needle fall. In some specimens, the needles remain for a long time, for several years; perennial thick shoots are dotted with still-living needles, while in other forms the needles are retained only on the shoots of the previous and the year before. The colour of the needles of Scots pine is also variable: alongside specimens with ordinary green needles, you can find forms with golden, silver or even white needles.

A great variety is observed in the shape of the crown. The angle of the lateral branches from the trunk is important for crown formation. There are forms of pines with a very sharp angle, in which the branches seem to be leaning against the trunk, and forms in which the lateral branches are almost perpendicular to the trunk axis. You can distinguish crowns with conical and umbrella-like shapes. In nature, there are also narrow pyramidal crowns formed by branches hanging down – almost weeping and crowns formed by strongly curved, sparsely branched knots.

Pine trees also show differences in the colour and shape of the bark. The colour of the bark varies from light yellow to red-brown and brick coloured. The lamellar bark consists of wide, more or less rounded laminae, while the scaly bark is made up of narrow scales.

Pines are also distinguished by the quality of their wood. Foresters have long distinguished between lodgepole pine, with its resinous, strong reddish wood, and honey pine, with its whitish, less durable wood. It is believed that these forms are inherent in different growing conditions: the condor pine grows in more drained urban areas, while the lungwort grows in more humid ones. On peat bogs, you can see a curly, low-growing form of pine. At the outcrops of chalk on the banks of Forest-Steppe rivers, chalk pine with a low curly crown, short needles and small cones is common. In nature, it is often observed that certain features seem to contribute to each other. For example, plate-bark pines usually have light green needles, a wide crown, and a long taproot. They grow in drier areas and have very strong wood. Scaly pines have a narrow crown, dark green needles, grow in wet areas and are characterised by inferior wood. Scale pines are considered to be less valuable than loblolly pines.

Task 3. Identify the main features of form diversity and peculiarities of their description in the common spruce (*Picea exelsa Link.)*.

***Common spruce* (*Picea exelsa Link.*).** Spruce, like pine, has a wide variety of forms. First of all, it is necessary to note the existence of two forms of spruce, which differ in the colour of young cones: green-cone and red-cone.

There are also significant differences in the shape of the seed scales of the cones. There are spruces with rounded cone scales (almost like silver spruce) and specimens with scales that are toothed to a greater or lesser extent. They also differ in the ratio of the length of the scales to their width.

There is considerable variability in the size of cones (from very large to small). The needles of different spruces also vary greatly in size; there are spruces with different colours of needles: light green, dark green, variegated white, golden yellow.

The existence of five types of spruce branching (according to Sylvain), which are hereditary, has been revealed:

1) comb-like – first-order branches grow more or less horizontally, and thin branches of the following orders hang down from them, forming a comb;

2) irregularly comb-shaped – branches of subsequent orders of different lengths and structures extend downwards from horizontally placed branches;

3) compact – knots are not long, thick; short branches of the second order are directed both up and down;

4) horizontally flat – branches of the second order and subsequent orders diverge in the same horizontal plane;

5) brush-shaped – the main thick and not long knot forms short branches of the second order, branches of different lengths extend from it upwards, to the sides and downwards.

It has been observed that spruce trees with different branching types grow differently. It is believed that under the same conditions, trees with a comb type of branching grow better than trees with other types of branching. According to the nature of the crown, two main forms of spruce can be distinguished: narrow-crowned – with short, horizontally directed branches of the first order and wide-crowned – with horizontal, long branches of the first order and hanging branches of the next order. You can find spruce trees with a weeping crown shape, spherical and columnar crowns. These forms are very important in forestry.

Spruce trunks also differ in bark. On this basis, a smooth bark form can be distinguished, in which the bark in the lower part of the trunk remains smooth and has a reddish-red hue until the age of 30–40 years. Another form is more common, in which the bark has deep piercing cracks that resemble the rough bark of a pine tree. In addition, there is a third form with greyish-coloured bark made of small square scales. Smooth bark spruce is fast-growing and has low-density wood with a high acoustic constant. This type includes the so-called resonant spruce, which is especially valued in the manufacture of musical instruments.

Two forms of spruce are distinguished by the time of young shoots appearance: early and late blooming. The latter is less likely to be damaged by late spring frosts and is therefore more valuable.

Task 4. Identify the main features of form diversity and peculiarities of their description in the common oak (*Quercus robur L.)*

Common oak (Quercus robur L.) The form diversity of the oak tree can be identified primarily by its reproductive organs. The female flowers of different forms differ in the colour of the stigma: it can be either reddish or yellow-green. They also differ in the number of female flowers that sit on one peduncle: usually there are 2–3 of them, but in some trees, peduncles with up to 10 flowers or more can be observed. Another characteristic related to this is the number of acorns on the fruit stalk. There are usually fewer acorns than flowers, since not all flowers form acorns, but oaks with more flowers on the fruit stalk also have a higher number of acorns on the fruit stalk.

There are several forms of fruit stalks according to their length. In the most typical form, the fruit stalk is about half the length of the leaf in which it sits. But there are also forms with much longer or shorter stalks.

The dendrological literature describes forms with stalks as long as the cover leaf or even longer. In some cases, fruit stalks several tens of centimetres long have been observed. Often, it is on these stalks that a larger number (6–8) of acorns are located. Rock oak forms can be found, with very short fruit stalks, only a few centimetres long, the acorns appearing almost sessile, like those of a sessile-flowered rock oak.

There is also considerable variation in acorn size and shape. There are trees with large acorns 5–7 cm long and up to 2,5 cm wide. Next to these, there are trees with very small, spherical acorns that are barely halfway out from under the ivy. In the forest, you can find trees with very thin and relatively long acorns, and those with pointed, egg-shaped or barrel-shaped acorns.

When studying the variability of such a trait as acorn size, it is important to remember that it is of significant importance. It has been proven that large acorns produce seedlings with greater growth energy, at least in the early stages of development. The boles of mature acorns on different trees are not the same, they can be more or less deep and cover part of the acorn, or only its base. The shape of the bole can be hemispherical, goblet, conical or flat. The colour of the scales of the acorn is also very diverse (from greyish-brown to sandy yellow). The scales are either thin, flattened, pressed or thick, tuberculate and swollen; rarely there are oak forms with very thin scales that are strongly separated.

Several oak species are distinguished by their leaf shape. This is based on the depth of the leaf blade, the shape of the leaf base, the colour and pubescence of the leaves, the size and length of the leaf, and the length of the leaf petiole. The most typical oaks are those with medium-length blades with a 1/3 cut into the leaf blade. You can also find oaks with short-lobed leaves, sometimes whole-edged, with almost no lobes. Along with these, there are specimens with a deeply dissected lobed blade, with long lobes. Sometimes the dissection of the leaf blade reaches almost to the central vein.

The lobes of the leaves can be rounded, blunt, sharp or pointed. In the common oak, the leaf base is usually «ear-shaped» or deeply dissected. Sometimes you can find specimens with very large «ears» pulled back. The wedge-shaped base of the leaf blade is very rare in common oak. This characteristic is typical for rock oak.

In addition to the most common form with a common green colour, yellow-leaved, red-leaved, yellow-spotted and white-spotted forms can be observed (most often in parks and other ornamental plantings, less often in forests).

According to the degree and type of pubescence of the oak leaves, several forms are distinguished: with bare, not pubescent leaves; with leaves pubescent from below with two-horned hairs that disappear on adult leaves; with short star-shaped hairs that cover the leaf more or less densely from below; with long star-shaped, multi-rayed hairs, especially long ones on the central vein of the leaf.

There is also a great deal of variation in such characters as leaf size and petiole length. Along with the typical form, in which the leaf is 5–15 cm long and 2–8 cm wide, there are trees with very large leaves, reaching a length of 20–25 cm and a width of 12–15 cm, as well as small-leaved forms with leaves less than 8 cm long and 2–3 cm wide.

The most typical crown of the common oak is tent-like, which is formed by powerful branches of the trunk extending in all directions at an acute angle from its axis and having branches with leaves at the level of the top or slightly below it. With such a crown shape, the top of the trunk is often invisible, as it does not stand out among the lateral branches. There are oak species with a pyramidal crown, in which the lateral branches are usually numerous and not very thick, growing at a very acute angle to the trunk axis.

Among the oak trees with this crown shape, you can find specimens with a wider crown or a narrower, columnar crown that resembles the shape of a cypress.

In addition to trees with a pyramidal crown, oak trees also have spherical and weeping crowns. In the latter form, long hanging branches and shoots create a distinctive crown character.

The trunks of the common oak tree are covered with a rough, cracked, usually dark grey bark in maturity. There are trees with bark that is lighter in colour, less deeply cracked and has a general appearance that resembles that of the common ash (a companion of oak).

Oak has forms that differ in wood quality. For example, there are trees whose wood first turns pink and then yellow after felling. The wood of such ‘pink’ oak is characterised by its thin layers, softness, good splitting and beautiful texture. Such wood is valued in the production of plywood and veneer, but is considered less durable than wood of a typical oak shape. Anatomically, pink oak wood is characterised by a relatively lower development of mechanical fibres, which are thin–walled and occupy a smaller area in the annual ring than in the typical form. The annual rings of pink oak have a greater number of large vessels in the spring part of the ring and a poorly developed summer part, which, as is known in oak, determines the density of the wood and increases its mechanical properties. ‘Pink’ oak is also characterised by relatively large sapwood and a correspondingly smaller heartwood.

In addition to its morphological forms, oak has interesting phenological and ecological forms. Two forms of oak are widely known, which differ in the time of leaf opening: the early leaf opening form is often called ‘summer’ and the late leaf opening form «winter», which opens 3–4 weeks later. The sign of blooming depends mainly on the weather conditions and the physiological state of the tree, this sign is not sufficiently stable and certain. In the same plantation, oaks do not all bloom and flower at the same time, which makes it difficult to determine. Therefore, it is necessary to take into account differences in the timing of blooming not in a few days, but in a few weeks. Given this, it is easy to determine that these forms occupy different positions in the oak forests of the Forest-Steppe. «Summer» is characteristic of high places, watersheds, upper parts of steep slopes and generally places characterised by dryness. «Winter» is characteristic of lower places of beams and lower parts of slopes, hence to areas that are more moist, but are «frost-resistant». The late blooming of oak in such fros-prone areas allows it to protect itself from the threat of damage by late spring frosts.

Task 5. Identify the main features of form diversity and peculiarities of their description in the common ash (*Fraxus excelsior L.)*

***Common ash* (*Fraxinus excelsior L.*).** Ash trees have forms that differ in fruit. The typical form has fruits with a wide, blunt wing. There are also forms with a sharp wing, which gave rise to the distinction of a special type of ash tree – the sharp-fruited ash tree (*Fraxinus oxycarpa*) and forms with a pit at the top of the fruit wing.

The diversity in the structure of the leaves of different forms of ash is manifested in the number of leaves of the complex unpaired leaf. Some ash specimens have leaves with a large number of leaflets (9–11), and at the same time there are forms with leaves consisting of only three leaflets or even one leaflet; the latter form is called (*Fraxinus monophylla*) and, in fact, has a simple leaf rather than a compound leaf. In addition, trees with reddish leaves can be found among ash trees.

The crown structure is also quite diverse. Most often, you can find ash trees with a wide, spherical crown formed by powerful branches that rise upwards. But in a larger number in the forest, you can also find trees with relatively short branches extending from slender trunks at almost right angles and the crown takes on a narrowly conical shape. In parks, and less often in nature, ash trees grow with a weeping crown shape, with branches and shoots that seem to hang down.

Ash trees also have phenological forms that differ in the timing of leaf opening. There are two ecological forms of ash. One is characteristic of upland positions and grows on limestone-rich soils in upland oak groves together with oak and other species typical of such habitats. The second form grows on alluvial soils of river valleys, usually with black alder, and is highly moisture-loving. The properties of these two forms are hereditary, and the moisture-loving form of ash grows worse than the dry ash when grown in drier conditions.

Task 6. Identify the main features of species diversity and peculiarities of their description in warty birch (*Betula verrucosa Ehrh.*) and fluffy birch (*Betula pubescens Ehrh.*).

Warty birch (Betula verrucosa Ehrh.) and **fluffy birch** ***(Betula pubescens Ehrh.).*** These birch species differ in their morphology and bioecological characteristics. The most characteristic differences between them are the presence of «warts» on the shoots of one species and pubescence on the shoots of another.

They also differ in the shape of leaves, seeds, seed scales, bark and crown shape. Fluffy birch grows more often on boggy soils, while warty birch grows in more drained areas. Both species can be found in forests, as well as specimens with mixed and intermediate characteristics of these species, which can be considered natural hybrids. In old trees of warty birch, the trunk at the base and up to a height of 1,5–2 m is covered with black, roughly cracked bark. Fluffy birch retains smooth white bark almost to the base until old age. Intermediate variations can be found between these types of bark.

Trees of warty birch have a crown with thin, hanging branches and shoots; fluffy birch is characterised by thicker, upwardly directed lateral branches, and therefore its crown does not have a weeping shape. In nature, you can also find intermediate forms between these types of crowns.

In the northern and north-western forests, a special form of warty birch grows – the so-called Karelian birch. It is distinguished by a special structure of wood, on the surface of which a very beautiful pattern resembling marble veins is obtained. Thanks to this characteristic, its wood is highly valued for interior decoration of buildings and the manufacture of artistic furniture and various crafts. The anatomical features of Karelian birch wood are already apparent in the first years of shoot growth. The peculiarity is that the heartwood is slightly angular at the points where the medullary rays exit. The latter are gathered in bundles or represented by a wide (collective) core bundle. These broad core bundles are clearly visible in cross-sections. At the boundaries of the annual rings, there is a bend towards the core, which results in wavy outlines of the annual rings. At the same time, the wide core beam seems to split into two parts, deviating from the radial direction. As a result, a pattern resembling the shape of a bird is formed on the end cut. All this creates horniness and ribbing of the trunk surface under the bark. Depressions and bends or furrows appear on the surface of the trunk. The wood forms areas of parenchyma, which consist of brownish cells and so–called stony cells. These areas of parenchyma disturb the correct positioning of mechanical fibres and vessels. As a result, a kind of wood is obtained. The peculiarities of the wood structure of Karelian birch are a hereditary trait.

The fluffy birch develops a shape that forms bumps and burls on the trunk. It is known as a burl birch. The burls appear due to the oblique and wavy layering of the annual layers of wood. Burls are valued in furniture and carpentry production.

Task 7. Identify the main features of form diversity and peculiarities of their description in Aspen (*Populus tremula L.*)

***Aspen* (*Populus tremula L.*).** Aspen has a wide variety of reproductive and vegetative organs. You can find forms of aspen that differ in the size of the flower earrings, in the size, colour and shape of the flower scales. The leaves can be distinguished into forms with large and small leaf blades; forms that differ in the general features of the blades (rounded, elongated, sharp-edged), forms that differ in the nature of the leaf blade edge (sharply toothed and serrated).

Aspen also differ in the degree of pubescence of the lower surface of leaves and young shoots.

There are aspen with weeping crowns and crowns that are close to pyramidal in shape. Of particular importance are forms that differ in bark colour. There are the following forms: dark bark, light bark and green bark. Sometimes you can also see a white-bark form, which is very similar in colour to birch. Dark-bark aspen has brown, cracked bark. This aspen is usually severely affected by rot, grows slowly and is less valuable than the light-barked aspen with thin, grey, smooth bark. The latter form grows quickly, is more resistant to rot disease and has more valuable raw materials.

The green-barked aspen is especially valued, as it has smooth green bark with a light grey bloom on the north side. This form grows mainly in drier areas, is characterised by good productivity and resistance to heart rot.

The giant shape of the plant is of great importance for aspen breeding. It is distinguished by its vigorous growth, large leaves, buds and shoots, wide annual rings and excellent quality wood, which contains a large amount of mechanical tissue with a lower content of vessels and storage tissue. The form has very dense wood and, due to its very fast growth, heals wounds quickly, which in turn protects against infections, especially heart rot.

The giant form of aspen is found in forests in groups, which is explained by their vegetative origin. Each group is essentially a root clone. Both male and female clones can be found. The giant form of aspen is reported to be a triploid. Aspen has a high ability to reproduce by root processes. There are phenological forms of this species that differ in the time of leaf opening: early and late. There are also forms of aspen with different demands on soil moisture or the ability to grow on saline soils, with aspen growing on saline soils having twice the amount of ash elements as normal forms.

Control questions:

1. Formal intraspecific diversity in tree species.
2. Name the main features of species diversity in common forest crops.
3. What is the heredity and variability of the main features in common forest species?

PRACTICAL WORK NO. 2

Topic: **FEATURES OF THE STRUCTURE OF VEGETATIVE AND REPRODUCTIVE ORGANS OF TYPICAL REPRESENTATIVES OF FOREST CROPS OF THE FOREST-STEPPE, STEPPE, AND POLISSYA**

Objective: to study the peculiarities of the structure of vegetative and reproductive organs of the main forest crops.

Materials and equipment: living representatives of these plants and their herbarium specimens.

Task 1. Study the structure of vegetative and reproductive organs of typical representatives of the families according to the following plan:

a) root: root system, modifications;

b) stem: its types, branching, leaf arrangement;

c) leaf: shape of the leaf blade, types of its division, compound leaves, venation;

d) structure of the flower: adroceus, gynoceus, perianth, types of inflorescences;

e) types of fruits and seeds.

Make the necessary drawings in the process of getting acquainted with the vegetative and reproductive organs of this family.

Task 2: To get acquainted with the herbarium of economically important representatives and species of typical representatives for the flora of the Forest-Steppe, Steppe and Polissya. Memorise their Latin and Ukrainian names.

Beech **(*Fagus*)** includes about 10 species, 2 of which are found in Ukraine. Staminate flowers in capitate inflorescences; pistillate flowers (2–4) surrounded by a common, bristly outside membrane; nuts are triangular, edible; leaves are entirely marginal. All types of beech are quite shade-tolerant, picky about soil and air fertility and moisture. They form either pure forest plantations – beech forests – or are included as an admixture in oak, hornbeam or dark coniferous forests. They provide valuable timber for furniture, riveting, fuel, etc. In Ukraine, to the west of the Zbruch River (Podillia), in Prykarpattia and Zakarpattia, there is a **forest birch (*F. sylvatica*)**, a powerful and beautiful tree up to 30–35 m in height. In the Mountainous Crimea (upper zone) and in the Caucasus, the **eastern b. (*F. orientalis*)** grows (Fig. 1).

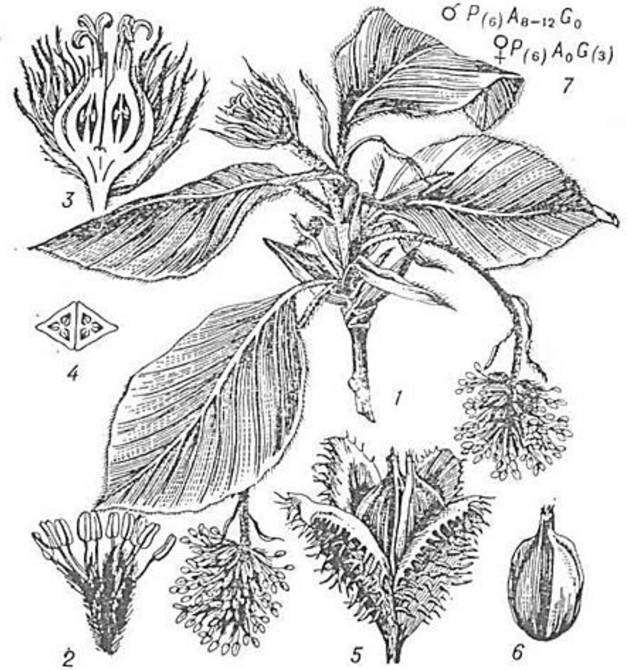

Figure 1. **Beech** (*Fagus sylvatica*):
1 – branch with leaves and inflorescences; 2 – staminate flower;
3 – pistillate flower; 4 – ovary in section; 5 – nuts with a plate;
6 – nut; 7 – flower formations.

Oak (*Quercus*) has about 600 species, including 3 in Ukraine. Staminate flowers in hanging earrings, 6–8-membered perianth, 6–10 stamens; pistillate flowers in capitate inflorescences; pistil of 3 carpels; three-nested ovary, with 6 seed germs, 5 of which are reduced during fruit development. The nut is cylindrical (acorn) at the base with a plate in the form of a bowl. The significance of oak in nature and human life is quite great. Numerous species of oak are the main forest-forming species of broadleaf and mixed forests.

The most important and widespread in the European forest zone is the **common or petiolate oak (*Q. robur:* Fig. 2)**. It is a large, up to 40 m tall, powerful tree with a spreading crown. It forms pure plantations called oak woods or grows together with hornbeam, linden, maple, ash, pine, etc. Oak is very durable. In Ukraine, there are many 500– to 600–year-old and even 800- to 1000-year-old oak trees that are valuable natural monuments and are protected by the state.

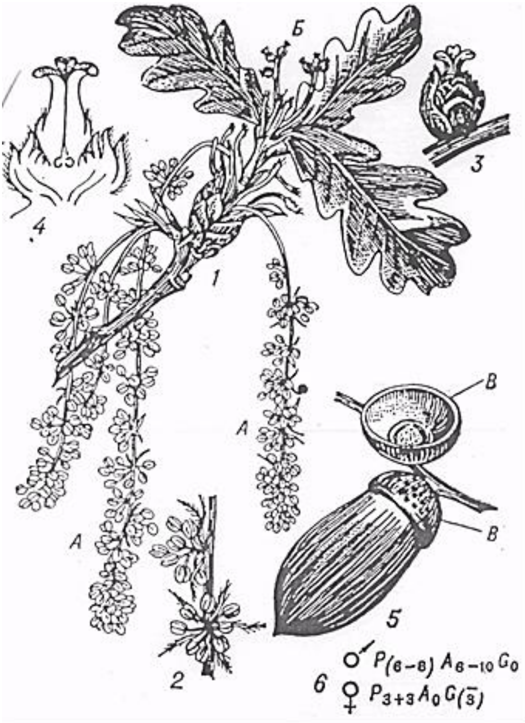

Figure 2. **Common oak** (*Quercus robur*):
1 – branch, with staminate (A) and pistillate (B) inflorescences;
2 – staminate flowers; 3,4 – pistillate flower in lateral view and section; 5 – acorn with calyx (C); 6 – flower formations.

Oak is a valuable hard and durable wood that is widely used as a building material, as well as furniture, sleepers, rivets, parquet, etc. Oak is also highly valued as the main species for field protection belts, steppe forestry and landscaping.

Other oak species in the local flora include the **rock oak** (*Q. petraea*), a large tree common in the forests of Prykarpattia and Transcarpathia, and the **fluffy oak** (*Q. pubescens*), a small tree that forms low-growing forests in the lower mountain belt of Crimea.

Among the introduced oaks, of which more than 30 species have been tested in Ukraine, the following should be mentioned: southern European species – **cork oak** (*Q. suber*), a valuable cork tree, the first plantation of which was created in Ukraine in 1820 in the Nikitsky Botanical Garden in

Crimea; **stone oak** (*Q. ilex*) – a beautiful evergreen tree; from the Transcaucasian species – **chestnut-leaved** (*Q. castaneifolia*) and **large-stemmed** (*Q. macranthera*); from the North American species – **boreal** (*Q. borealis*) and **swamp** (*Q. palustris*); both species have beautiful red leaves in autumn; they are common in many parks and forestries in Ukraine.

Hazel (***Corylus*:** Fig. 3) has about 15 species, distributed in Europe, Asia and North America, with one species in the Ukrainian flora**.**

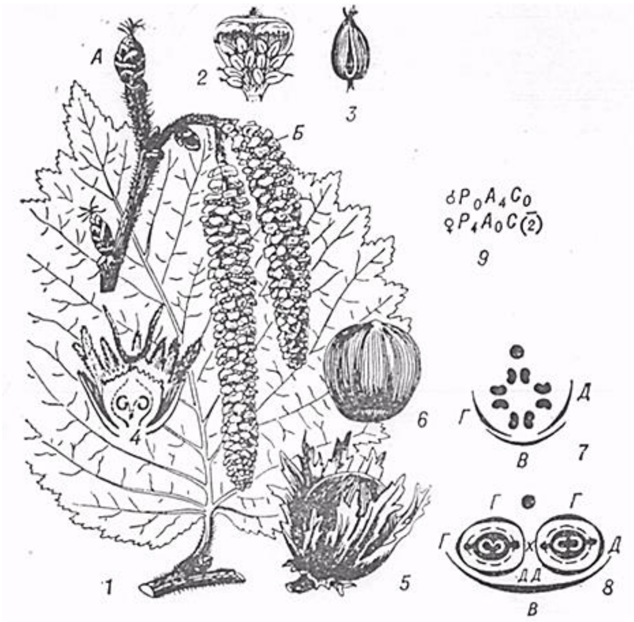

Figure 3. **Hazel** (*Corylus*):
1 – part of a shoot in summer and a flowering spring shoot: A – pistillate flowers; B – staminate earrings; 2 – staminate flower; 3 – stamen; 4 – pistillate flower in section; 5 – 6 – nut with and without a carpel; 7, 8 – diagrams of staminate flower and pistillate dichasis; C – cover leaf; D, E – bracts; 9 – flower formulas.

Staminate flowers in one-flowered racemes; pistillate flowers in two-flowered racemes. The nut is wingless, buried in a sheath. The most important and widespread species is **common L. avellana** (*S. avellana*), a bush up to 4–5 m tall; it grows as an undergrowth in broadleaf forests of Europe, up to the Urals. It is a valuable nut-bearer, an indicator of high soil fertility. In gardens and parks of Ukraine, the following are cultivated in some places: **tree nut, or bear nut** (S. *colurna*), a large beautiful tree up to 25 m tall with a spreading crown, originally from the Caucasus, and large nut, or **Lombard nut** (*S. maxima*), a large bush up to 6–8 m tall, originally from Southern Europe. It is a valuable food, oil and ornamental crop.

Alder (*Alnus*) includes about 30 species, of which 3 are found in Ukraine. Staminate flowers in three-flowered racemes with four stamens; pistillate flowers in tw-flowered racemes; wingless nuts contained in a lignified cone. *V. glutinosa* (*A. glutinosa*, Fig. 4: – tree up to 20–25 m tall, with dark brown bark and glutinous dark green leaves; common in the forest zone of Europe and Asia.

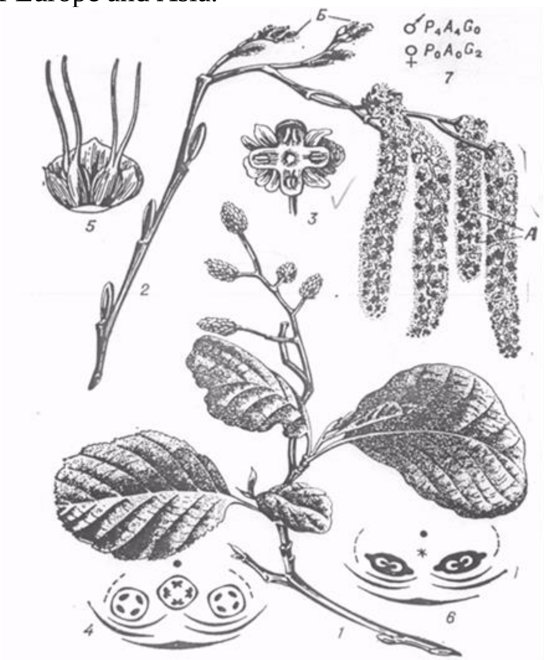

Figure 4. **Alder** (*Alnus glutinosa*):
1 – branch with cones; 2 – branch with staminate (A) and pistillate (B) inflorescences; 3 – three–flowered dichasium of staminate flowers; 4 – its diagram; 5 – two–flowered dichasium of pistillate flowers; 6 – its diagram; 7 – flower formulas.

It grows in excessively humid places with running water, on the banks of rivers, lakes and other water bodies in Ukraine; it often forms pure plantations known as alder forests. Alder wood is used to make furniture, underwater and surface structures; the bark is used as tanning raw material. Less common in Ukraine is the **grey alder** (*A. insana*), a small tree (up to 10–15 m tall) with smooth grey bark. It is found in Polissya, in the Forest-Steppe, most often in the Carpathians, where it sometimes forms dense thickets in the place of spruce and fir felling. In the Carpathians and the Alps, a large alder-like shrub, **green dusky** (*Alnus viridis*), grows along mountain streams, rivers and in damp places, forming dense thickets.

Birch (*Betula*) includes more than 50 species, including 8–9 species in the flora of Ukraine. Flowers in three-flowered racemes; stamens 2; nut flattened, with two membranous wings. The hanging or warty basswood (*B. pendula or B. verrucosa*; Fig. 5) is a beautiful tree up to 20–25 m tall, with smooth white bark and long hanging branches covered with small dark warts.

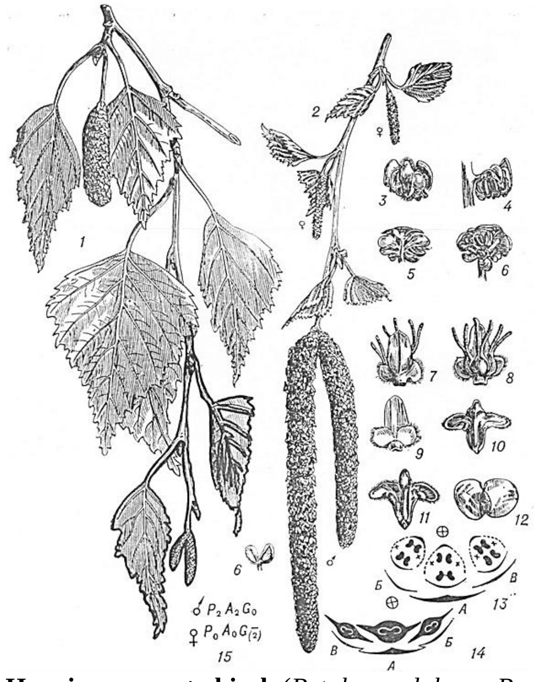

Figure 5. **Hanging or warty birch** (*Betula pendula, or B. verrucosa*):
1 – branch in summer; 2 – branch in spring with pistillate and staminate inflorescences; 3 – 6 – staminate flowers; 7, 8 – pistillate flower dichasiums outside and inside; 9 – integumentary scales; 10, 11 – bracts; 12 – fruit; 13 – diagram of pistillate flowers dichasia; 14 – diagram of staminate flowers dichasia; A – integumentary

Control questions:

1. Write a formula and diagram of the stamen and pistil flowers of the hanging birch.
2. What is the difference between birch, alder and hazel?
3. What is ephemeroids?
4. Name the species of birch trees common in your region. What do you know about them?
5. Geographical distribution, ecology of beech.
6. Life forms and features of vegetative organs.
7. Structure of inflorescence, flower, fruit, seed.
8. Importance in nature and human economic activity.

PRACTICAL WORK NO. 3

Topic: **BIOLOGY OF FLOWERING, FRUITING AND SEX DETERMINATION IN THE MAIN FOREST-FORMING CROPS**

Objective: to study the peculiarities of the structure of generative organs, flowering and fruiting periods of the main forest species.

Materials and equipment: herbarium specimens, notebook, ruler, pencil.

In the breeding process, the biology of reproduction of forest tree species in different geographical and weather conditions, pollen distribution, etc. is of great importance. Without this, it is impossible to achieve positive results during hybridisation. Therefore, it is very important for a breeder to know the flowering characteristics of each tree species: timing, duration, pollination methods in natural conditions, pollen maturation and duration of pollen shedding, duration of the period when pistils are able to receive pollen, flower structure, distribution of bisexual receptacles on the tree, etc.

Seed yield forecasts can also be made at the flowering stage, starting with the establishment of flower buds, which allows for the systematic harvesting of seeds for a large volume of reforestation work.

Tasks. Using additional literature and herbarium specimens, learn about the peculiarities of flowering of forest species, note down the timing of flowering, its duration, methods of pollination in natural conditions, the timing of fruit ripening, and draw the structure of flowers and their distribution on the tree.

Poplar is a wind-pollinated dioecious plant. Pistillate and staminate flowers are collected in inflorescences – hanging cylindrical earrings that form from lateral flower buds on last year's shoots.

Balsam poplar blooms before the leaves open. Female catkins up to 10 cm long, yellowish bracts, not pubescent, perianth covers the ovary below its half, bracts are two-lobed, red. Staminate catkins up to 8 cm long, stamens per flower 12–30, anthers pink (Fig. 1).

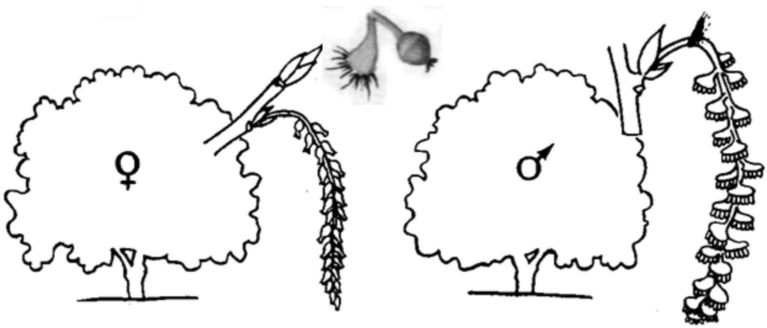

Figure 1. **Male and female earrings in poplar.**

Determination of sex in poplars. When dissecting the generative buds of poplar, look for individual flower rudiments in the form of green «envelopes» 2 mm in size. If subtle green anther rudiments are visible in the folds of the envelope, then this flower is male, i.e. the tree from which the flowers were taken is male (Fig. 2). Predicting the sex of poplars is of great practical importance for hybridisation, landscaping, etc.

The **common oak** blooms simultaneously with the leaf opening; it is pollinated by the wind. Oak flowers are bisexual. Male flowers are collected in inflorescences – hanging earrings. There are 10–15 flowers in one inflorescence. Staminate earrings are formed either from special generative buds in the upper part of last year's shoots or at the base of spring shoots. The perianth consists of 5 to 6 greenish leaves and 4 to 12 stamens on short stamen filaments (*Fig. 3*).

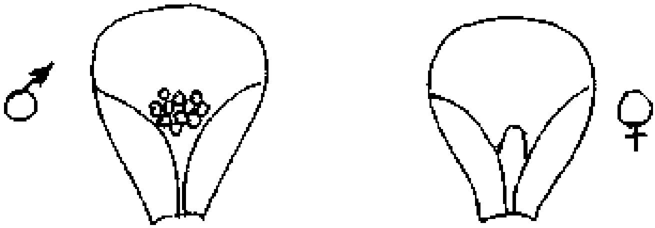

Figure 2. **Aspen flower buds: male and female.**

Female flowers are formed only on spring shoots: a pedicel emerges from the leaf axils in the upper part of the shoot, on which a flower with a six-part, underdeveloped perianth is placed. The ovary is three-nested with two seed germs in each nest. There are three columns, with burgundy stipules. Usually, one of the six seed germs is fertilised, the rest die, and a fruit is formed – a single-seeded, single–nested acorn.

Fig. 3. **The structure of flowers and inflorescences of the common oak.**

During flowering, the ovary is underdeveloped, so fertilisation in oak occurs in 1,5–2,0 months. As a rule, after fertilisation, the first wave of ovary shedding is observed (late June – early July).

The **hanging birch** is a monoecious plant with bisexual flowers that bloom at the same time as the leaves bloom. Staminate earrings are located at the ends of the branches, hanging (5–6 cm long), flowers are almost sessile, covered with brownish scales with a one- or two-leaved perianth. They form in late summer and spend the winter on trees. In spring, they elongate, hang down, and pollen begins to fall. They bloom before the leaves open or simultaneously with their opening. Pollination takes place with the help of the wind. There are flowers (about 100 pcs.) on the axis of the earring, and 2–6 stamens under the leathery scales.

Pistillate earrings (2–3 cm long) are formed on spring shoots, green, upwardly directed, bearing bracts on the axis, in the axils of which there are three flowers without perianth (*Fig. 4*).

The pistil is single with a lower ovary and two reddish filamentous stigmas. The ovary is two-nested, with one seed embryo in each of them.

During fertilisation, one of the two seed embryos dies. The flowers are arranged in a spiral pattern, there can be up to 300 of them.

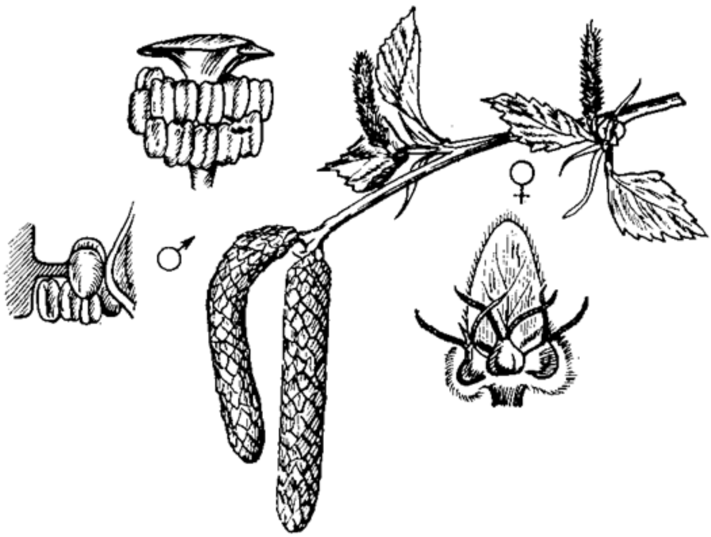

Figure 4. **The structure of flowers and inflorescences of the hanging birch.**

The fruit is an oblong nut with two membranous wings. Fruiting is annual. The fruits ripen by the end of summer and begin to disperse, which occurs gradually throughout autumn and winter. In a birch forest, up to 35 kg of seeds per 1 ha can fall annually. Hanging birch in a free state begins to bear fruit at the age of 10, and in a plantation – at 20–25.

Forest beech blooms immediately after the leaves open and is pollinated by the wind. Staminate flowers are collected in capitate inflorescences hanging on a long stem. The inflorescences are located on last year's shoots or at the base of this year's shoots. The formed male flower buds are thicker and more convex than the vegetative buds. Staminate flowers consist of a 5-, rarely 7-lobed simple perianth and 8 to 12 stamens. Pistillate flowers are collected in 2–3 in the leaf axils in the upper part of the shoot and are surrounded by a 4-lobed perianth and contain an ovary with three columns with purple stipules. The nest contains 2 seed embryos, but usually 1, rarely 2 develop (*Fig. 5*).

Like staminate flowers, pistillate flowers are set in the year preceding flowering, but 1 to 2 months later than staminate flowers. Fruit ripening occurs in autumn in the year of flowering, and falling out – after the opening of the ivy in the second half of autumn.

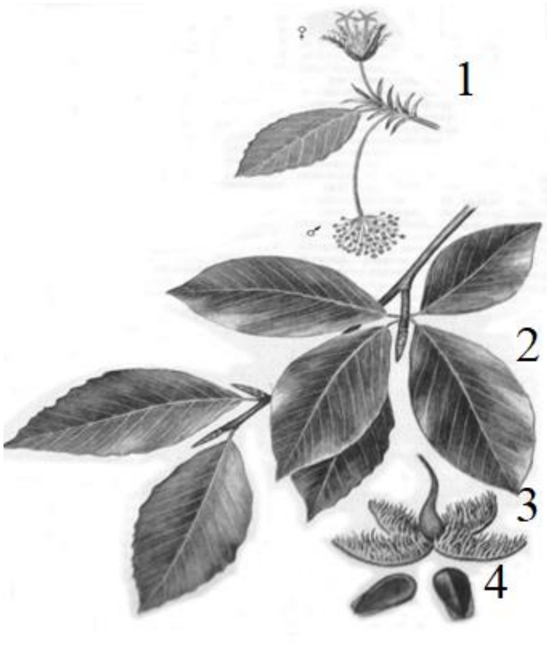

Figure 5. **Structure of inflorescences of European beech**:
1 – Spring shoot with male and female inflorescences;
2 –Summer shoot; 3 –Open cupule; 4 – Fruits.

Acer platanoides blooms before the leaves fully unfold. The flowers develop on the current year's shoots and are gathered in racemes or panicles. In most species of maples, there are three types of flowers: bisexual, female, and male. Acer platanoides is pollinated by insects. The flowers have a double perianth. The petals are located at the edge of the receptacle, with the ovary in the center, transitioning into a long style with a bifurcated stigma. The ovary is two–celled, flat, and winged. Up to 10 stamens are located at the edge of the receptacle (*Fig. 6*). Physiologically female and physiologically male flowers are more commonly found.

Figure 6. **Structure of different types of flowers of Acer platanoides.**

Carpinus betulus blooms simultaneously with the unfolding of leaves. The staminate flowers are in lateral narrow-cylindrical catkins, consisting of bract scales and 4–12 stamens with bifurcated filaments and hairy anthers at the base. The pistillate flowers are in few-flowered terminal catkins, sitting in pairs in the axils of small bract scales, which fall off early. The ovary is two-celled, inferior, with one ovule in each cell (*Fig. 7*). The fruit is a one-celled, one-seeded, almost woody nut.

Figure 7. **Structure of inflorescences and flowers of Carpinus betulus**: 1. Female catkin at the end of the shoot; 2. Shoot with two staminate and one pistillate catkins; 3. Staminate flower; 4. Stamen; 5. Two pistillate flowers with bract; 6. Pistillate flower without bract; 7. Mature fruit with bract; 8. Fruit without bract; 9. Cross-section of the fruit; 10 Cotyledons; 11. Shoot with vegetative and male flower buds; 12. Seedlings.

Ulmus laevis blooms before the leaves appear. Numerous clusters of small flowers develop from flower buds located at the tips of branches. The flowers are bisexual, on long pedicels, brown in color, with 2 stigmas and 6–8 stamens with orange or purple anthers (*Fig. 8*). This plant is both wind and insect-pollinated. In the flowers, the stigmas mature earlier than the stamens. Fruiting begins in May. The fruits are samaras, oval in shape.

Figure 8. **Structure of inflorescences and flowers of Ulmus laevis**:
1. Flowering shoot; 2. Shoot with leaves and fruits; 3, 4. Flower and pistil; 5, 6. Fruit with seed; 7. Seed; 8. Shoot with vegetative and generative buds.

Pinus sylvestris male and female cones develop on the current year's shoots. Male cones are grouped together to form a strobilus, located at the base of young shoots. Each male cone consists of an axis with scale-like stamens (microsporophylls) arranged in a spiral. Pollination occurs with the help of wind. Female cones develop at the tip of the shoot. The cones consist of paired scales: a bract scale and a seed scale. On the seed scale, there are two ovules (*Fig. 9, 10*). Fertilization occurs in the thirteenth month after flowering. Overall, it takes 1.5 years from pollination to seed maturation.

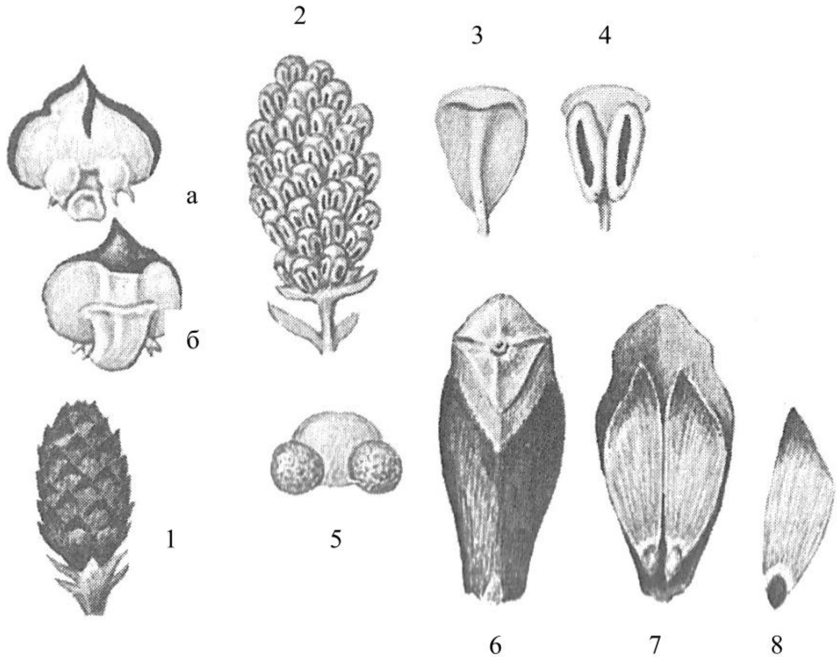

Figure 9. **Female and male strobili of Pinus sylvestris**:
1. Macro-strobilus (a – seed scale with two ovules, b – bract and seed scales); 2. Male cone with microsporophylls; 3, 4. Microsporophyll; 5. Pollen; 6.Woody seed and bract scales; 7. Woody seed scale with two winged seeds; 8.Seed.

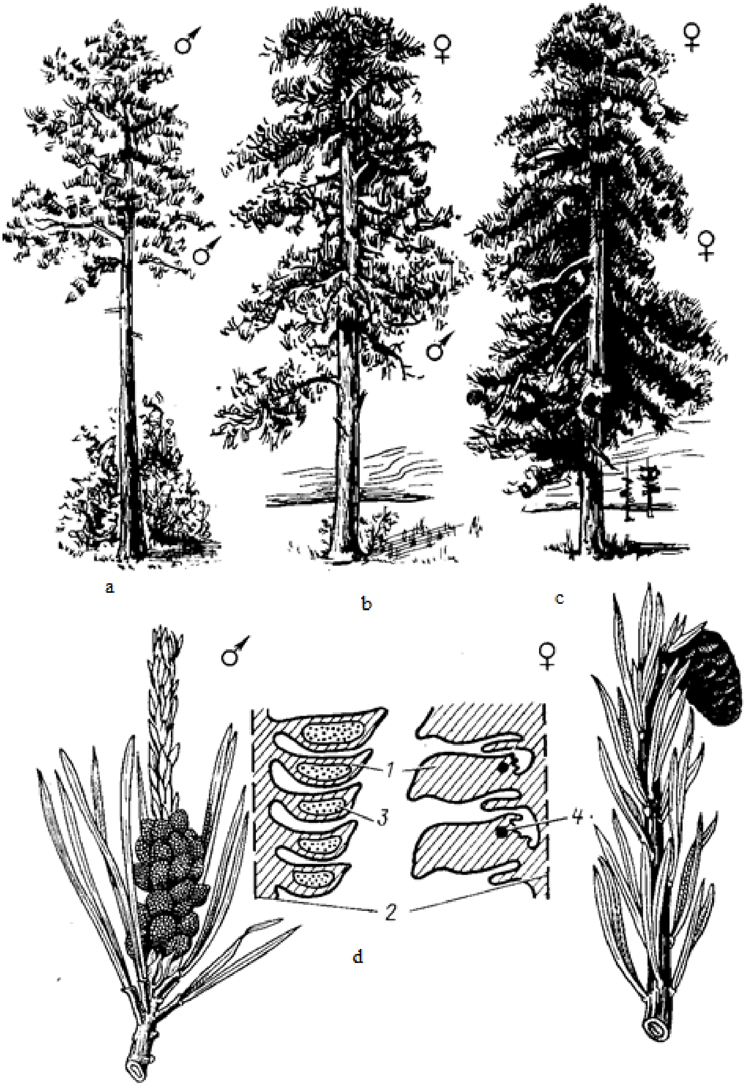

Figure 10. **Structure of generative shoots of Pinus sylvestris:** a. Sparse-crowned male-type tree; b. Mixed–type flowering tree; c. Dense-crowned female-type tree; d. Structure of male and female strobili; 1. Microsporophylls; 2. Strobilus axes; 3. Microsporangium; 4. Macrosporangium.

Larix decidua is a monoecious plant. Its male and female cones sit singly on short shoots (*Fig. 11*). Female cones are light green or crimson. The structure of larch cones is similar to that of pine cones. After pollination, the cone develops rapidly, and the seeds mature in autumn. Male cones are located singly on short shoots in the form of yellow balls, 5–10 mm long. The pollen lacks air sacs. Pollination occurs simultaneously with the unfolding of needles or immediately after, in April-May. The cones mature in the autumn of the flowering year, with an ovoid or oblong-round shape, 1,5 to 3,5 cm long. Mature cones open either immediately or in early spring. The seeds are small, ovoid, with tightly attached wings. Fruiting begins at about 15 years of age. The periodicity of abundant fruiting is 6–7 years.

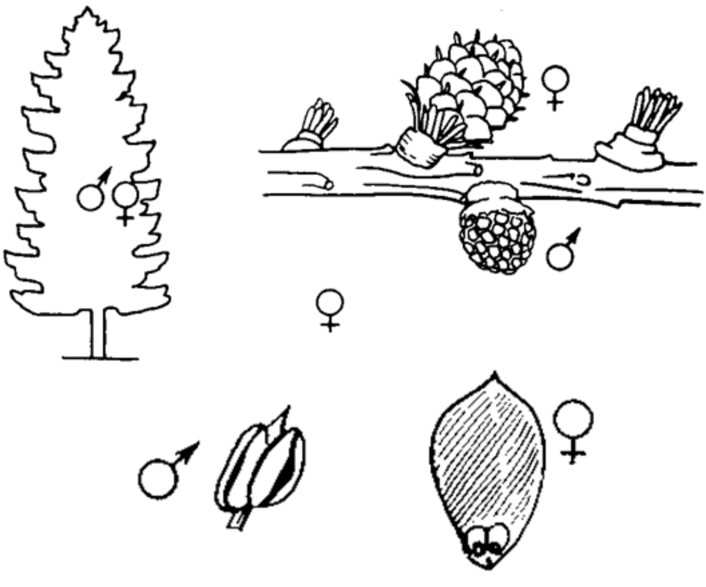

Figure 11. **Structure of generative shoots of Larix decidua**:
1. General view of the tree; 2. Short shoot with macro– and micro-strobili; 3. Micro-strobilus; 4. Bract and seed scales.

Parthenocarpy is often observed in Larix, resulting in seed formation without fertilization, lacking endosperm and embryo. Therefore, cross-pollination is essential for Larix, as they almost never set seeds from their own pollen.

Picea abies is a monoecious plant, blooming from late April to early May. Female cones during flowering range from green to dark red, cylindrical in shape, and are located vertically at the tops of last year's shoots. The ends of the seed scales are bent outward during flowering to facilitate pollen penetration to the ovule. After fertilization, the seed scales close, and the cone hangs down from the shoot. Male cones (singly or in groups of 3–8) develop from lateral, rarely terminal, buds on last year's shoots. After flowering, they quickly dry up and fall off. Picea abies blooms from late April to early May. Pollination occurs with the help of wind. Microstrobili are formed by microsporophylls, each bearing two pollen sacs. The pollen has two air sacs. Megastrobili are spindle-shaped or ovoid, pendulous (*Fig. 12*). The seeds are winged, elongated, and mature in the year of flowering, in October–November.

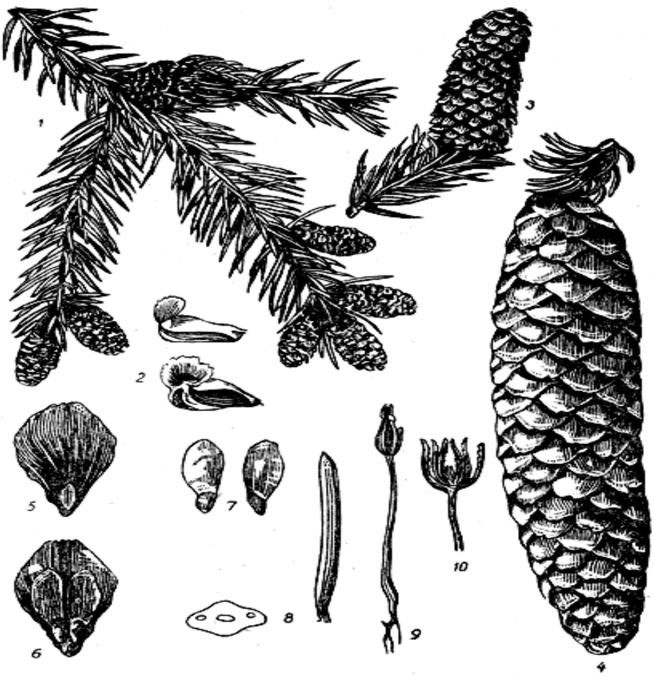

Figure 12. **Structure of generative shoots of Scots spruce**:
1 – shoot with male cones; 2 – stamens; 3 – shoot with female cones; 4 – mature cone; 5 – seed scales from the outside; 6 – seed scales from the inside; 7 – seed; 8 – needles; 9 – seedlings.

Control questions:

1. What is the significance of the knowledge of the peculiarities of flowering of forest species in the breeding process, and what is the reason for this?
2. What are the flowering periods of the hairpin species of forest trees?
3. When does fertilisation occur in Scots pine?
4. How long does it take from pollination to seed ripening in Scots pine?
5. When do larch and spruce cones ripen?
6. Name the wind-pollinated monoecious deciduous tree species?
7. What are the phenological forms of the common oak?
8. What breed has male and female specimens?
9. How is the sex of poplars predicted and what is the significance of this in the national economy?
10. Name the forest species that are characterised by periodicity of fruiting and what is it?

PRACTICAL WORK NO. 4

Topic: **METHODS OF VEGETATIVE PROPAGATION**

Aims: to learn methods for obtaining planting material of forest trees and shrubs with certain qualities

Materials and equipment: workbook, tables, pencil.

Vegetative propagation means the formation of new independent plants with the characteristics and properties of the parent plant from individual plant vegetative organs – roots, stems, leaves or their parts. It is based on the ability of living tissues to regenerate the whole plant (to restore lost parts).

Under natural conditions, vegetative propagation is most pronounced in plants growing in conditions unfavourable for seed reproduction. The methods of vegetative propagation of woody plants in nature are diverse: sprouts from dormant buds on rhizomes (linden, oak); root sprouts from adventitious buds on roots (plum, aspen); layering (spruce, viburnum); sprouts from stump or trunk from dormant buds (vegetative regeneration of many species).

- During artificial vegetative propagation, all types of natural propagation are used, as well as others, which can be conditionally grouped into the following four methods: propagation by parts not separated from plants, propagation by parts separated from plants, propagation by grafting, and clonal micropropagation.
- The purpose of vegetative propagation is primarily to obtain plants with certain qualities: intensive growth, desired crown shape, colour and shape of leaves, etc., which are not transmitted to offspring through seed propagation or are transmitted to a small number of specimens. In recent years, due to the intensive development of forest breeding and the transfer of seed production to a selection and genetic basis, the role of vegetative propagation in forestry practice has increased significantly.
- In modern conditions, vegetative propagation methods in forestry are used for;
- industrial breeding of clone varieties valuable in terms of productivity, wood quality, yield, decorative qualities and other attributes;
- preservation of valuable hereditary forms of woody plants that are rarely found in nature;
- obtaining mass quantities of homogeneous planting material for the purpose of creating special plantations.

Task 1. Describe and draw in the workbook the technology of propagation by parts not separated from plants

Obtaining new plants from parts not separated from the mother specimen is based on natural methods of vegetative propagation and includes propagation by stem cuttings, root and rhizome sprouts.

Propagation by cuttings is used mainly for the propagation of lilacs, roses, viburnum buldeneum, linden and its forms, sea buckthorn, hazel, spirea, forsythia, European euonymus, elderberry, bindweed and other plants. In practice, various methods of propagation are used: vertical and horizontal cuttings, shoots in grooves with a bracket, snake, etc.

For propagation by **vertical cuttings**, the mother bushes on a special plantation are cut to a ‘stump’ in early spring, leaving 12–18 cm of shoot above the ground (*Fig. 1*). In the year of pruning, shoots develop on the stumps. Over the summer, as they grow, the shoots are spudded 1–3 times, bringing the soil layer thickness to 20–30 cm. In autumn, at the end of the growing season, the soil is shovelled away, and all rooted shoots are separated from the mother bush with a garden knife or secateurs.

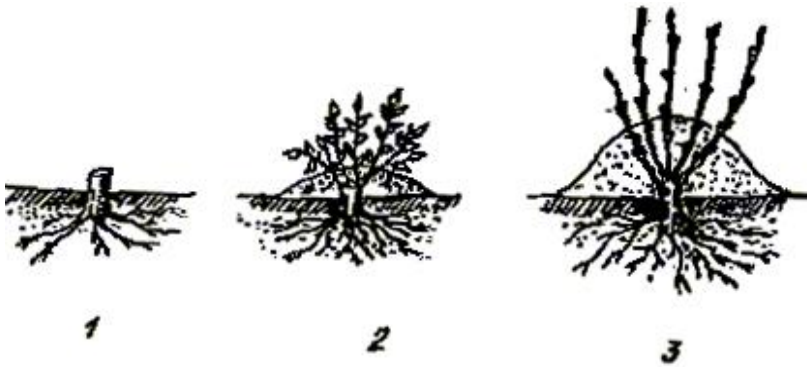

Figure 1. **Propagation by vertical layering.**

Propagation by **horizontal cuttings** (*Fig. 2*) is used in the cultivation of common jasmine, warty spindle, lilac, and viburnum buldenege. The mother bush is prepared as in the case of propagation by vertical layering. In the spring of next year, 3/4 of the shoots that have grown from the stump are laid out horizontally on a cleared, well loosened and fertilised soil surface, and pressed firmly to the ground with wooden hooks. Break out the lower buds that are adjacent to the soil. Young shoots soon grow from the remaining buds, which are left open. Sprinkle the shoots of the mother bush with soil. With the growth of young shoots, they are also sprinkled with soil two or three times during the summer with a layer of up to 20 cm. The rooted shoots are grown for another year on the plantation or separated from the mother bush and planted in a school.

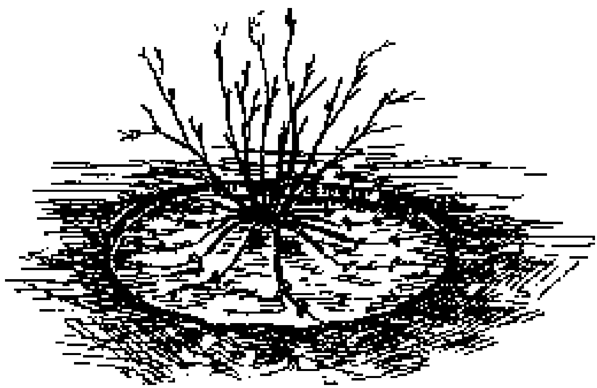

Figure 2. **Propagation by horizontal layering.**

Gooseberries and some other species are propagated by diverting shoots into the grooves with a bracket (*Fig. 3*). In spring, grooves up to 10 cm deep are dug around the bush at a distance of 20–30 cm. Annual shoots are laid out in the grooves and fixed to the bottom with wooden hooks. The tops of the shoots are bent upwards and tied to vertical pegs. The grooves are covered with organic-rich soil. By autumn, roots form on the shoots in the grooves. You can separate the shoots in autumn or spring of the following year.

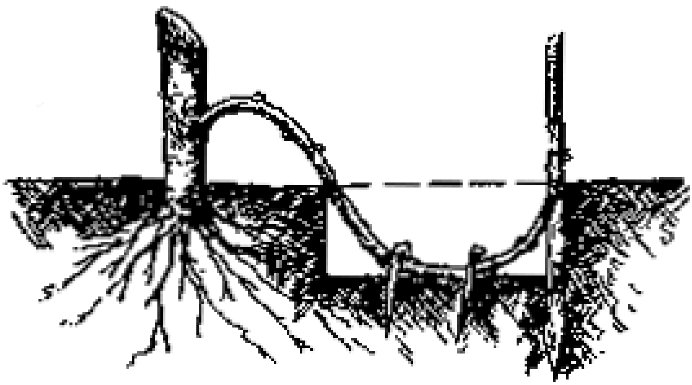

Figure 3. **Propagation by diverting shoots into a groove with a bracket.**

Wild grapes, Schisandra chinensis and other vines with long, flexible shoots reproduce well by diverting shoots into the **grooves with a snake** (*Fig. 4*). This method is similar to the previous one. It allows you to get as many cuttings from one shoot as there were bends. Sometimes, for better rooting, the shoots are pulled with soft wire. This method is called the Dalem method.

Figure 4. **Propagation by diverting shoots into grooves with a snake.**

Propagation by root shoots. This method is used to produce new plants of aspen, silver poplar, white poplar, bird cherry, turf, white acacia, olive, scumpia and some fruit trees (pear, plum). In most species, sprouts are formed on roots located at a depth of 1–3 cm.

Propagation by rhizome (stolon) sprouts – plants are obtained from sprouts that form on special modified shoots – stolons (common lilac) and rhizomes.

Task 2: Read and draw in your workbook the process of propagation by parts separated from plants

The starting material for propagation is the parts separated from the plant, called cuttings. Cuttings are divided into root cuttings, stem cuttings (winter cuttings), stem cuttings (green cuttings) and leaf cuttings. Nurseries use mainly stem cuttings, less often root and leaf cuttings. New plants are obtained by rooting cuttings in open or closed ground.

Propagation by root cuttings is used for species that produce root sprouts – alder, white acacia, aspen, linden, sea buckthorn, linden, cherry, plum, etc. Cuttings are taken in October-November or early spring before the growth of the ground part begins, mainly from two-year-old roots. For this purpose, the root system of the mother trees is excavated and roots with a diameter of 0,5–1,5 cm are separated with secateurs. Before planting, they are stored in trenches or in a cellar in wet sand. Before planting, the roots are cut into cuttings 5–15 cm long. When planting, it is important not to confuse the basal and apical parts of the cuttings. To do this, cut the upper ends (apical part) perpendicular to their length, and the lower ends (basal part) at an angle. The cuttings are buried in the soil, lightly crushing the upper end. Of the shoots that develop from the cuttings, leave one of the most developed, and break off the rest.

Propagation by winter lignified stem cuttings. This is the easiest and cheapest method of vegetative propagation. It is widely used for growing many tree species (poplar, willow, currant, grapes, etc.). Cuttings are obtained from 1–2 year old, well-lignified, vegetative (formed from stumps on special mother plantations), vigorous shoots from the middle part of the crown, which are cut in autumn after leaf fall or in spring before the start of the growing season. Practice has shown the advantage of cutting shoots in autumn, which are stored in wet sand, cellars or snow. In the spring before planting, they are cut into cuttings 25–30 cm long. It is better to take the middle part of the shoot with well-developed buds for cuttings. The thickness of the cutting in the upper part should be at least 5–7 mm. The upper cut of the cutting is made straight above the bud, and the lower cut is made at an angle of 45° below the bud. Bundled cuttings of 50–100 pieces are treated with growth stimulants or ringed to form a callus on the lower (basal) part. Prepared cuttings are planted for rooting in the cuttings department or directly in the nursery for growing seedlings. When planting, make sure that the top bud of the cutting is above the soil surface or slightly crushed.

Propagation by green (summer) semi-lignified cuttings is widely used in ornamental horticulture for growing thuja, roses, spruce, boxwood, junipers, spirea, jasmine, actinidia, clematis, weigela, forsythia, common viburnum, currant, lilac, etc.

For plant propagation, cuttings are used from shoots of the current year that have finished or are finishing their growth and have not yet lignified. Green cuttings of most species are cut 5–7 cm long with one (lilac) or two (rose) internodes. The upper cut of the cutting is made above the leaf petiole, the lower cut is made under the petiole or 1 cm below it, where roots are best formed. In plants with opposite leaf arrangement, the lower cut is straight, and in plants with spiral leaf arrangement, the lower cut is made at an angle of 30–45° opposite the bud.

To reduce the evaporative surface and transpiration, the leaf surface of all hardwood cuttings with large simple and compound leaves is reduced by half. Spruce and juniper cuttings are harvested with a «heel» by tearing off shoots from the mother shoot (*Fig. 5*), and cypress cuttings with a «spine». In some species, only the cuttings of the upper part of the shoot root well (actinidia, scumpia, hydrangea, most conifers), so only one cut is made – the lower one.

Figure 5. **Appearance of cuttings:**
1 – with a reduced leaf surface; 2 – with a «heel».

Green cuttings are treated with a growth stimulant before planting. Mostly aqueous solutions of stimulants are used (*Table 1*), but sometimes alcohol solutions and powder are also used.

Table 1: **Concentration and timing of treatment of cuttings with aqueous solutions of growth stimulants and vitamins**

Growth stimulant	Root cuttings		Green and leaf cuttings		Lignified cuttings	
	concentra-tion, mg/l	exposure, hours.	concentra-tion, mg/l	exposure, hours.	concentra-tion, mg/l	exposure, hours.
Heteroauxin	50–70	6–8	150–200	8–12	200–250	18–24
Indrolyl butyric acid (IMC)	20–25	6–8	30–50	8–12	50–70	18–24
Naphthyl acetic acid (NAA)	20	5–7	25–30	8–12	50	18–24
Vitamin C	500	–	1000–2000	–	1000–2000	–
Vitamin B1	50	–	100–200	–	100–200	–

Alcoholic solutions are prepared as follows: dissolve 8–10 mg of heteroauxin, 4–6 mg of naphthylacetic acid or 8–10 mg of indoleacetic acid in 1 ml of 50 % alcohol. Processing (exposure) of cuttings lasts 10–15 seconds.

Powders are prepared at the rate of up to 30 mg of heteroauxin, IMΦ or NAA per 1 g of talc (charcoal), 50–100 mg of vitamin C and 5–10 mg of vitamin B1.

After processing, the cuttings are planted in greenhouses with a plastic cover and artificial fog in a layer of sand or other substrate (vermiculite, perlite, expanded clay) to a depth of 1,5–2 cm according to the 5x5 or 7x7 cm pattern. The substrate is well moistened before planting. During the rooting period of green cuttings in the greenhouse, the air temperature should be maintained at 25–30 ° and the humidity at 85–95 %.

The technology for growing plants from green cuttings involves transplanting rooted cuttings from greenhouses or greenhouses into open ground for growing or into nurseries to produce seedlings. Rooted cuttings, if they have formed a well-developed root system, are transplanted in late July or early August. In the year of rooting, white turf, juniper, and thuja are transplanted.

It is advisable to leave cuttings of most species in greenhouses for the winter. Spruce cuttings are kept at the rooting site for two years. During wintering in greenhouses or hotbeds, they must be hardened by airing, opening the frames, etc.

Control questions:

1. Name the methods and types of propagation by parts inseparable from plants and the features of their implementation.
2. Name the methods and types of reproduction by parts of plants and features of their implementation.
3. Reproduction by layering.
4. Propagation by root cuttings.
5. Propagation by stem lignified cuttings.
6. Propagation by green stem cuttings.

PRACTICAL WORK NO. 5

Topic: **THEORETICAL BASIS OF GRAFTING OF FOREST SPECIES**

Aims: to get acquainted with the basic terms and concepts used in the vegetative propagation of forest species by grafting.

Materials and equipment: pruning shears, garden knife, budding knife, garden saws, plastic wrap, adhesive tape, garden putty.

Selected tree varieties are most often propagated vegetatively, as the properties of the desired variety are not fully transmitted through seeds. Grafting is a type of vegetative propagation in which vegetative parts of plants with different hereditary backgrounds are artificially joined. As a result of grafting, these plants grow together and continue to grow as a whole. This method of vegetative propagation allows all the characteristics of the mother organism to be passed on to the offspring. Thus, there is a mutual exchange of plastic substances between the two components of the graft, which sometimes changes their properties, i.e. the possible influence of the stock on the scion.

A mother tree is an individual from which buds and cuttings for grafting are taken. In forestry, it is a plus tree.

Scion – a cutting or bud from the mother tree that is grafted (grafting material). Cuttings are taken from the best uterine specimens, the most typical for a given variety. For plants with opposite leaf arrangement, cuttings are cut with 2–3 pairs of leaves perpendicular to the shoot axis under the node, and for alternate arrangement – with 2–3 leaves, obliquely against the lower bud. Short, lateral, thin, weak shoots of deciduous plants are cut with a heel. In plants with large leaf blades (tree hydrangea), they are shortened by half to reduce evaporation.

The rootstock is the tree on which the scion is grafted. The rootstock is primarily responsible for the growth of the grafted plant, but also affects its resistance to disease and frost. Today, in fruit growing and forestry, low-growing rootstocks are used to produce stunted trees that bear fruit earlier.

There are various methods of grafting, depending on the species, climate zone, etc., but they are all the same in that the graft is fused to the rootstock in the cambial layers. The graft fusion is hindered by an insulating layer, which usually occurs on the third or fourth day as a result of the death of the outer layers of the cell membranes of the scion and rootstock. Later, as a result of resorption, the insulating layer partially disappears. The cambium tissues of the scion and rootstock close, and common conductive tissues of wood and bark are formed. Strengthening of the grafting strength occurs due to the continued separation of cambium and the growth of new layers of wood.

The time for grafting depends on the condition of the scion and rootstock, as well as on weather conditions – it is accelerated in warm and humid weather, and delayed in cold and dry weather. The optimum temperature is +18…+22 °C. The fusion process is also faster if the area of cambium contact on the cuts is larger. This is achieved by budding, while grafting with cuttings is more difficult.

Topophysis is the preservation of the age and developmental characteristics of the mother tree in the scion. The phenomenon of topophysis is very common in conifers (araucaria, cryptomeria, dwarf forms of fir and spruce), in which cuttings taken for grafting from lateral branches retain their characteristics. In a grafted plant, branching occurs in only one plane, i.e. the new plant completely retains the planar structure of the lateral shoot and does not form a tiered, symmetrical arrangement of branches. In such plants, cuttings are taken only from the apical main shoot.

Incompatibility of scion with rootstock. If all the requirements for grafting are met, the scion-rootstock fusion usually captures one or two rows of cambium cells. These rows of cells are superimposed longitudinally one on top of the other. When the scion and rootstock are fully compatible, the connection is strong and nutrients are successfully transferred from scion to rootstock and back again. If there is even a weak biological incompatibility between the components, the cells do not grow together so firmly as to form a mechanically stable organism. At some stage, biotic or abiotic factors lead to the scion being rejected by the rootstock. As a result, the stem breaks at the grafting site, and the rejection site resembles a smooth saw cut.

Age of scion and rootstock. In silviculture, seedlings or saplings aged 3–5 years are used for rootstocks, and they are selected in such a way that a scion can be applied to them with high quality. The scion is taken from a plus adult tree. However, there is still no consensus on the specific age of the scion. At present, the selection of plus trees is mainly based on phenotype, and, therefore, trees (especially conifers) of about 100 years of age are selected when their characteristics become pronounced. The impact of such grafting on seed offspring is small fruits or cones and poor seed quality. The plantation as a whole does not last long, as the plants continue to age in stages. Therefore, it is more efficient to select plus trees by genotype, i.e. by growing offspring from seeds. In this case, the age of the mother tree will be 20–60 years, which will ensure better plant viability, longer plantation operation and high seed quality.

The choice of grafting time depends on the climatic conditions of the area. Thus, in the middle zone, grafting can be carried out for almost six months: in January – March – the so-called winter grafting on pre-prepared rootstocks in a warm room; from early April to mid-June – spring grafting with a cuttings; at the beginning of bud swelling – spring grafting with a bud. At the end of June – stone fruit budding; in the second half of July and most of August – budding of all fruit species. The calendar time for grafting within each industry depends not only on the climatic conditions of the area, but also on the weather conditions of each year. This is especially important for budding.

In general, it can be noted that the success of grafting depends on several conditions:

- timely harvesting and proper storage of cuttings for spring grafting;
- correct implementation of the cutting technique;
- compliance with the required cleanliness of tools and the scion/rootstock junction;
- speed of vaccination;
- careful matching of the cambial layers of scion and rootstock;
- the density of the scion and rootstock sections;
- protection of plants from drying out (tight tying of grafting sites, shading).

Task 1: Learn the basic methods of vaccination.

Budding is a grafting technique in which a dormant bud (eye) with a piece of bark is used as a scion. This is the most common method of grafting all fruit crops. The advantages of this method are that it ensures good growth of the grafting components and a low requirement for grafting material.

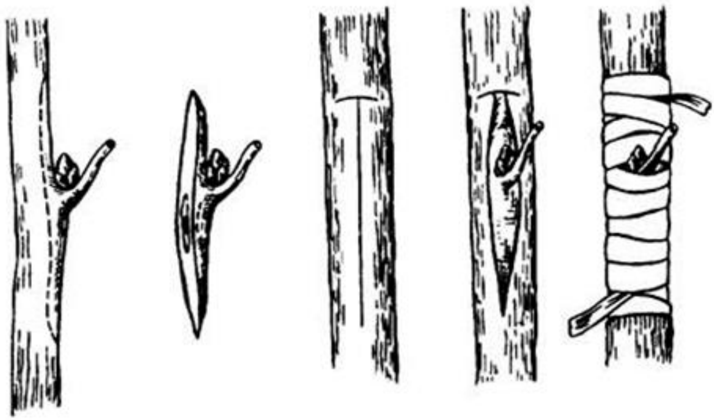

Figure 1. **Grafting in the t-split.**

Copying is a method of grafting cuttings that has many varieties. The most common and easiest is simple copying. Along with it, other methods of grafting are also used: improved copying, bark grafting, split grafting, butt grafting (Figs. 2, 3) and others.

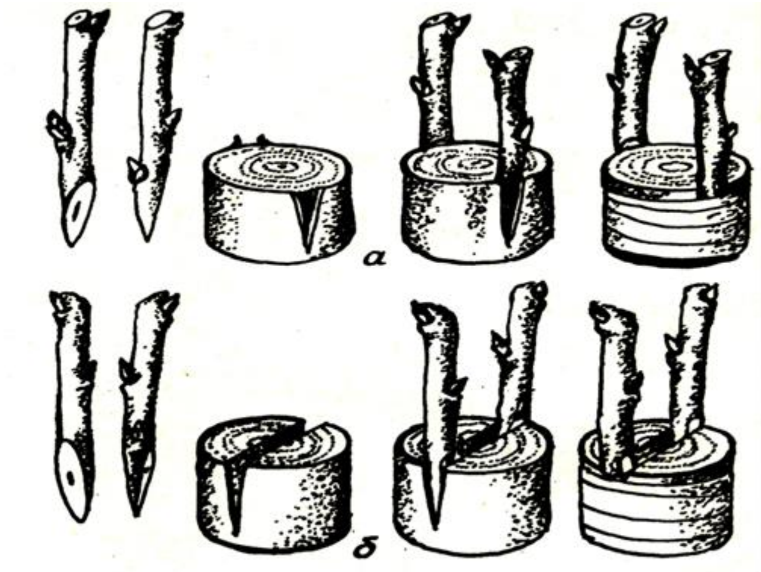

Figure 2. **Bark (a) and cleft (b) grafting.**

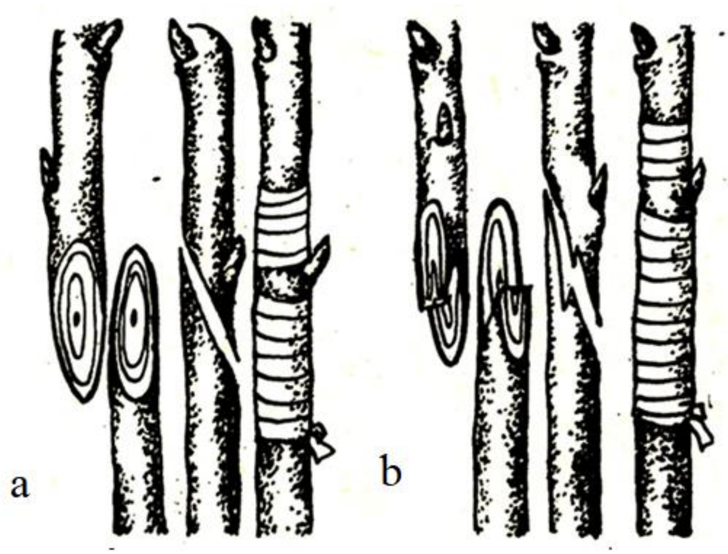

Figure 3. **Copying**: a – simple; b – improved.

Copulationis the grafting of plants by bringing their branches closer together without separating the grafted part from the mother plant (*Fig. 4*). Oval pieces of bark are cut from the scion and rootstock (cut only to the cambium), connected at the cut points and tied. After complete fusion, the scion is separated from the mother plant, leaving the graft on the roots. In this way, distant forms are spliced, which cannot be grafted in other ways. In plants under natural conditions, there are cases of fusion without human intervention of individual branches and trunks of one organism, or two growing side by side. This phenomenon is quite common in deciduous tree species. A classic example of a very easy fusion of branches and trunks of the same tree at the point of contact can be observed in the ironwood tree (*Rarotia persica*).

Decapitation grafting is a cuttings grafting that has a number of features. After the scion and rootstock are fused, the grafted plant is cut (decapitated) at the fusion site so that the tissues of both grafting components are preserved on the cut. Additional buds give rise to new shoots. This creates very beautiful bushy ornamental forms used in green building.

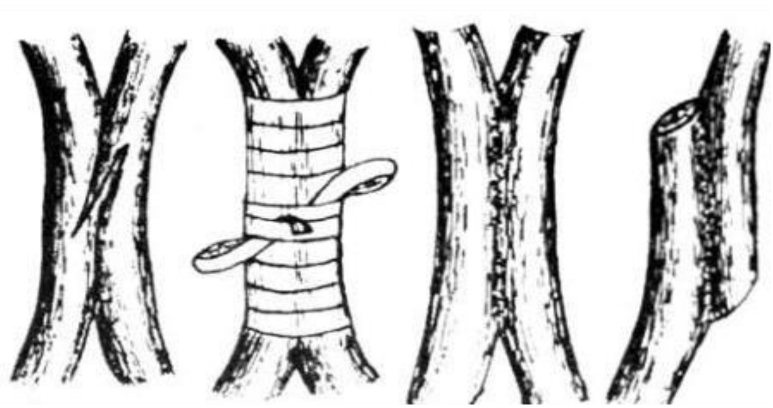

Figure 4. **Copulation.**

Grafting the embryo onto new cotyledons. This method of grafting is used for large seeds (e.g. acorns, beans). An embryo is cut out of the seed and an embryo from another seed is inserted in its place.

Grafting with germinated seeds onto an adult plant (*Fig .5*). A horizontal T–shaped fold of the bark to the cambium is made on the rootstock, the bark is peeled off and the germinated seed is inserted (Fig. 5). Then tying is done, coating.

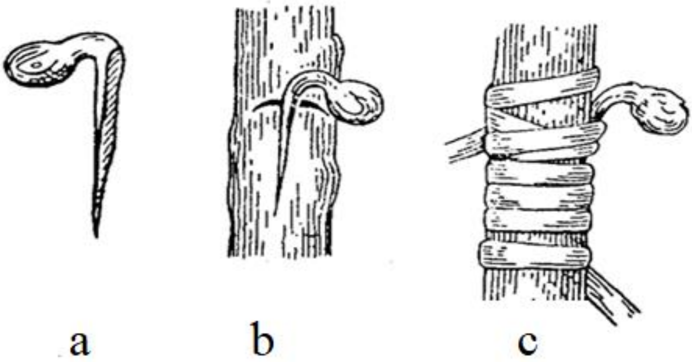

Figure 5. **Grafting germinated seeds onto an adult plant:**
a – a seedling with an oblique cut on the spine; b – a T–shaped cut with an inserted seedling; c – the grafting site.

The method of grafting oak «in the bag» (*Fig.6*) is to use young plants 3–5 years old as a stock, the trunk is completely cleaned of lateral shoots before grafting, then, at a convenient height for grafting, the trunk is cut with a garden knife at an angle of 35–40 °. The scion cutting with two buds is cut with a budding knife from the winter shoot, the lower end of which is cut in a wedge–shaped manner and the bark on this cut is completely cut off to the cambium. Then the upper section of the rootstock is squeezed with the thumb and forefinger of the left hand so that the bark lags behind the wood and a «bag» is formed between them, into which the wedge-shaped section of the scion is placed, wood to wood.

The vaccination site is tightly tied with a narrow strip of plastic wrap, all exposed areas of the cuts are covered with garden putty or plasticine, and a protective plastic wrap is put over the entire scion and tied tightly at the bottom. The protective bags and bandages are removed immediately after the rootstock has taken root. This method has proven itself on many other types of forest trees.

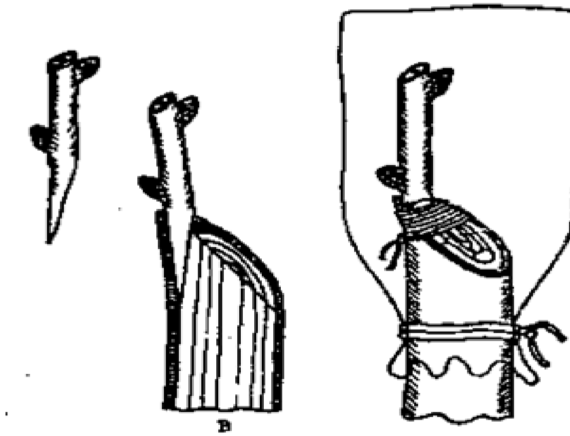

Figure 6. **Scheme of oak grafting using the «bagged» method.**

Task 2: Perform budding grafting on cut shoots and draw a simple and advanced copying on the cut shoots.

Control questions:

1. What is the importance of vaccination in the breeding process?
2. What is the purpose of grafting in forest species?
3. How does the age of plants affect the success of grafting?
4. What are rootstock and scion?
5. What is the purpose of ablation in breeding?
6. Name the forest species for which budding can be used?
7. What factors determine the choice of vaccination time.

PRACTICAL WORK NO. 6

Topic: **MASTERING THE TECHNIQUE OF GRAFTING CONIFERS ON CUT BRANCHES**

Purpose of the work: To consider the most common methods of grafting pine, spruce, fir, cedar, larch.

Materials and equipment: pruning shears, garden knife, budding knife, garden saw, razor blade broken in half, electrical tape, plastic wrap, adhesive tape.

Objectives: To learn the basic methods of grafting conifers and to perform on cut shoots and draw the grafting of a pine tree, for example, with the heartwood on the cambium of the central shoot.

For conifers, 3 methods of grafting can be considered the most successful:

– in a split with an apical shoot;

– in a side cut;

– by grafting the heartwood onto cambium and cambium onto cambium.

The latter 2 methods are the most common: grafting with graft core onto rootstock cambium for pine and cedar (Fig. 1), and grafting with cambium onto rootstock cambium (for spruce).

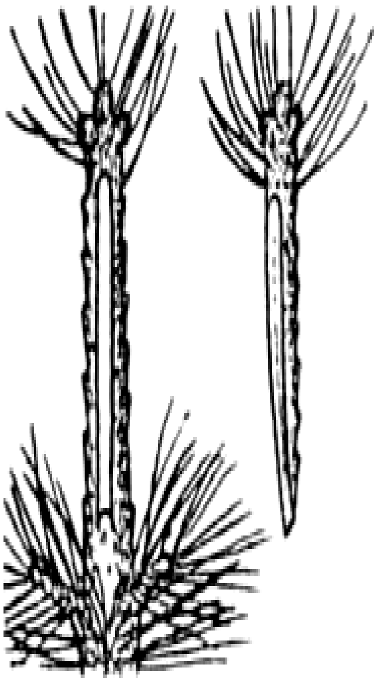

Figure 1. **Grafting pine with a heartwood example on the cambium of the central shoot**.

The advantages of the cambium grafting method are as follows: the destruction of the axial shoot of the rootstock is excluded, so that in case of unsuccessful grafting, the rootstock can be reused; the combination of cambial layers in the grafting components is clearly ensured, which increases the percentage of successful grafting.

The grafting procedure for these methods is approximately the same and consists of the following operations.

– cuttings are cut from a plus tree;

– pine needles are plucked to the apical bud, spruce needles are cut with a blade, as part of the bark is torn off to the wood when the needles are pulled (spruce wood is white and dry, the colour of the cambium is pale green, resin immediately appears);

– the graft to be grafted should be 5–7 cm long, the thickness of the cutting should be at least 4 mm, 10–14 needles should be left at the top (assimilation apparatus);

– the length and width of the cuts on the scion and rootstock should be the same;

– first, the cut is made on the cutting, and then on the rootstock, and only on the cambium;

– when grafting with a core on cambium (pine), the cutting is taken by a bunch of needles, placed on a board and directly under it, the blade is deepened to the core, the cutting is split along the core and at the bottom it comes out on a sharp wedge;

– the cut should not be touched with your fingers so as not to contaminate it;

– place the cutting on the prepared rootstock, combining the cambial layers;

– when tying with threads, first fix the lower part of the cutting, then check its connection with the open cambium of the rootstock, and finally, with a spiral rare turn of the thread, the cutting is fixed to the bunch of needles. After that, in a downward direction, the turns of thread are applied thickly to the end of the cutting;

– after 2–3 weeks, remove the tying material and cut the axial (central) shoot. The ends of the branches of the upper whorl are also cut off;

– the end of the rootstock shoot that remains in the spring of the following year is cut off at the grafting site or used to tie the growing scion to it to give it a vertical position;

– due to the fact that conifers are rich in resin and resinification immediately occurs at the cut site, coating of coniferous grafts is not required.

During breeding work with forest tree species, it is very important to have low-growing specimens that bear fruit. This facilitates tree species hybridisation work, simplifies pollen collection and pollination of macro-strobiles. To produce fruiting low–stemmed forms of pine, a cutting from an adult tree (30–50 years old) is grafted onto a young seedling, while to produce male specimens, cuttings are taken from shoots on which only anthers are formed annually. To obtain female specimens, cuttings are harvested from shoots where only female cones are formed.

Grafting is carried out by the method of splitting the central shoot (*Fig. 2*). The grafting technique consists in making a longitudinal (up to 1,5 cm) shoot split at the top of the stock (the top may be removed). A wedge-shaped, pointed cutting is inserted into the cleft so that the bark of the cutting coincides with the bark of the rootstock. The grafting site is tied and covered with garden varnish. The next year, 2–3 % of the grafted plants bear fruit, and in the third year – 40 %. At the same time, scions harvested from male pine shoots form only anthers, and scions from female shoots form only cones.

Thus, scions taken from an adult tree that bears fruit retain their sex and annual fruiting on a young rootstock.

Figure 2. **Scheme of pine grafting in the central shoot split.**

Control questions:

1. How is the propagation of pinewoods by grafting used in forestry breeding?
2. What are the most successful methods of grafting pines?
3. How are low–stemmed forms of pine produced?
4. What is the significance of low-stemmed, fruiting forms of pine in the breeding process?

PRACTICAL WORK NO. 7

Topic: SELECTION OF PARENTAL PAIRS FOR CROSSBREEDING AND DRAWING UP ITS PLAN

Objective: To get acquainted with the method of intraspecific, interspecific and intergeneric hybridisation, to learn how to select parental forms, to study the peculiarities of the transmission of hereditary traits and to draw up a crossing plan.

Material and equipment: tables, additional literature, workbook, pen.

To obtain new forms of plants using the method of sexual hybridisation, an important issue is the selection of plant pairs for crossing. A hybrid organism contains a variety of developmental possibilities, unlike a non-hybrid organism, whose development is determined by its conservative heredity, which has been formed over a long period of time during the formation of the species. The realisation by a hybrid organism of a particular developmental opportunity depends on external conditions; therefore, by selecting them, one can achieve a particular result.

The widest potential development opportunities for a hybrid are created if its nature contains sharply different properties of the parents. If the original forms are close in nature to each other, then the hybrid cannot be expected to be superior, it will follow the path of its parents in its development; if the parental forms are very different in their properties and characteristics from each other, then their hybrids will have great opportunities for development; on the contrary, development in the appropriate direction can produce a new plant variety with different properties.

Systematic and geographical distance is a prerequisite for obtaining new forms of plants that are valuable in practical terms during hybridisation. The systematic distance between two species means that the phylogeny of these species is sharply different, and that their history and, consequently, their hereditary nature are different. Geographical distance means a sharply different adaptability of species to external conditions, different requirements for the energy inherent in the plant genotype, which were formed during their phylogenetic development under the influence of certain external conditions, under the control of natural selection. Hybrids that originate from crossing systematically and geographically distant species should have a wide range of developmental possibilities and the ability to adapt to the conditions of the new environment to the fullest extent possible.

Objects for hybridisation can be various tree and shrub plants that are of varying importance in forestry and agroforestry. Intraspecific crosses (between representatives of the same species, but belonging to different forms, ecotypes or climates), interspecific crosses (between representatives of different species belonging to the same genus) and intergeneric crosses (between representatives of different genera of the same family) can be carried out with them.

Planned crosses can only be carried out if there are plants capable of flowering and fruiting of the species to be crossed. In other words, it is necessary that the species to be used as mother plants grow at the point where the crossing is to be carried out, except for species that can be crossed on cut branches. Branches with flower buds of such species are transported a considerable distance from their habitats to the place of work. The pollen required for this purpose can be delivered (under certain conditions) over a longer distance without significant loss of viability.

Task: 1. Write down the features that should be taken into account when selecting pairs for crossing.

When selecting pairs for crossing plants, you first need to set yourself the task of what features and properties the hybrid should have. This is the basis for the selection of parental pairs. To do this, it is necessary to know the biological characteristics of the breeds, their requirements for various environmental factors (light, moisture, heat, soil conditions) and take into account the specific conditions in which the specimens of the species intended for crossing grow. In addition, the conditions of the research and the conditions in which the hybrid plant is planned to be grown are taken into account.

Task 2: Describe the objects that can be used for crossing. Write down the peculiarities of the transmission of hereditary traits associated with the age of the plant and the sex of the plants used for hybridisation.

It is necessary to know the degree of crossbreeding between different species. When planning crosses of all categories (intraspecific, interspecific, intergeneric), the following should be borne in mind

a) healthy, not exhausted specimens of the intended species should be used as the mother plant, otherwise weak offspring may be obtained. Mother plants pass on their characteristics to the offspring, usually more fully than the parent plants;

b) in order to ensure successful crossing, it is necessary to take young plants that have just entered the fruiting stage, preferably those that are in flower for the first time. In this way, you can expect to get the best results in terms of hybrid fruit and seed yield. It should be noted that young plants have a lower degree of transfer of their hereditary properties to the hybrid generation compared to older plants with an established hereditary basis. Therefore, if certain properties of the parent species in hybrids are to be weakened, it is necessary to use a young plant as the mother plant in crosses. In the case when it is necessary to obtain the predominance of maternal properties and qualities in hybrid plants, the mother plants are selected from a number of older specimens;

c) local species and forms that are sufficiently resistant and adapted to local conditions of existence are particularly capable of transmitting properties and qualities to offspring. When crosses are made with such species, the resulting hybrids are highly biased towards local species and forms rather than those originating from other regions;

d) the same applies to wild and cultivated forms. Wild forms usually have a greater ability to transmit their properties and traits to offspring, while the power of transmission of hereditary properties of cultivated forms is much less;

e) the plants to be crossed should be selected from geographically remote areas or from ecologically heterogeneous habitats. This applies to distant hybridisation;

f) in addition to geographical and ecological distance, phylogenetic distance should be taken into account; when selecting parents, preference should be given to species that are distant in systematic terms. In some cases, such a trait as growth rate is more pronounced in hybrids obtained from closer crosses.

Task 3: Create a crossbreeding plan and describe the individuals used for this purpose.

To obtain positive results, it is necessary to use special tables that indicate the crossability of different species with each other. They are based on the experience of interspecific crosses conducted by domestic and foreign forest breeders (*Table 1*).

Once the pairs of plants to be crossed have been selected, it is necessary to start drawing up a crossing plan, which should indicate the species to be hybridised and the planned number of female flowers to be pollinated with pollen from one or another species. When drawing up a crossing plan, the flowering biology of the species should be taken into account and crossing combinations should be envisaged where flowering occurs simultaneously in both parental forms or where the paternal form flowers before the maternal form. In combinations in which the female form blooms before the male, it is practically impossible to cross, as pollen will be obtained after the mother species has faded.

Table 1: **Characteristics of woody plants used for crossing**

№	Indicators	Maternal species	Parental species
1	Title		
2	Habitat		
3	The main properties that characterise the species (growth rate, relation to light, soil conditions, winter hardiness, relation to moisture, etc.)		
4	Description of the trees used for crossing: A) habitat; B) conditions of existence; C) age of the tree; D) origin of the tree; E) tree dimensions: height, diameter at 1.3 m crown diameter, height of crown attachment; F) whether it grows on its roots or is attached; G) the degree of clearing of knots and fullness of the tree; H) tree condition, damage, diseases, etc. I) fruiting of the tree.		
5	What are the properties of this species and this tree of this species were selected for crossing		

Notes. The planned crossing combinations are marked in the respective columns with a '+' sign or a number indicating the number of female flowers to be pollinated with pollen of the respective species.

To select pairs for crossing, we draw up the following table, which justifies the choice of pairs (*Table 2*).

Table 2: **Crossing plan**

Names of female species (♀)	Names of the species used as male (♂)			

Fill in the tables and the journal of crossing forest plants. Draw conclusions to the work.

Journal of forest plant crosses

№ п/п	Characteristics of the mother plant					Characteristics of the of the father plant				Date of pollination	Recording the results	Note
	Breeding sample no.	Age	Location in plantations	Location of the flower in the crown	Castration and isolation time	Breeding sample no.	Age	Location in plantations	Pollen collection time			
1	2	3	4	5	6	7	8	9	10	11	12	13

Control questions:

1. What is a variety? Varieties-populations, varieties-lines, varieties-clones.
2. Requirements for varieties in production.
3. Source material in plant breeding. Natural populations: wild species, local varieties and populations, samples of world collections.
4. Source material in plant breeding. Hybrid populations: within a species and populations from crossing different species and genera.
5. Selection of parental pairs for crossing. Types of crosses.
6. Methods and techniques of crosses.
7. Difficulties of crossing different species and genera and ways to overcome them.
8. Heterosis of plants and its use.

PRACTICAL WORK NO. 8

Topic: **INTRODUCTION TO THE MORPHOLOGY OF TREE POLLEN AND DETERMINATION OF ITS VIABILITY**

Objective: To study the morphological features of wood pollen and methods for determining its viability.

Materials and equipment: microscope (8x and 20x lenses, 7x, 10x and 15x eyepieces), special chambers for hanging drops, which are mounted on slides and made of paraffin (slides with specially made recesses in them can also be used); cover slips; dissecting needles; glass sticks; spatula; tweezers; petroleum jelly; alcohol (for washing pore glasses), batiste, filter paper, distilled water; pollen germination media (different media are used for different types of pollen).

Pollen is a microspore formed in the anthers or microsporangia of all seed plants. In naked-seeded plants, pollen is formed in microstrobilis, and in covered-seeded plants – in anthers of staminate or bisexual flowers. The biological role of pollen is to carry male germ cells (gametes), which are called sperm in plants.

The genetic role of pollen is the formation and transfer of male gametes as carriers of hereditary traits on the paternal line.

According to the method of pollination, forest species can be:

Anemophilous (pollen is carried by the wind) are most tree species: pine, spruce, larch, birch, aspen, etc., which form the uppermost tier in tree stands. Their pollen is dry, crumbly, easily spread by the wind, the pistil, in most cases, is issued from a flower and is adapted to catch pollen in the air, flowering begins simultaneously. The pollen grains of anemophilous plants are small, dry, lacking sculpture, i.e. the structure of the exine is smooth, pollen is produced in large quantities (*Fig. 1*).

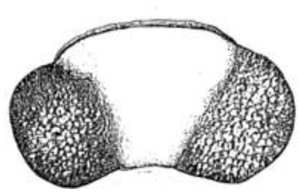

Figure 1 **Pollen structure of conifers (Scots pine).**

Conifers (except larch) have air sacs. Anemophilous species usually bloom before the leaves open (birch, alder, aspen, oak). This contributes to the long and unhindered spread of pollen, which can fly over long distances (*Table 1*).

Table 1: **Probability of the range of pollen transport by wind of different taxa** [after Sladkov, 1967]

Taxon name	Pollen drift range
Larix (larch)	several hundred metres
Pinus (pine)	500 – 1700 km
Picea (spruce)	300 – 400 km
Abies (fir)	1250 – 1300 km
Betula (birch)	250 – 300 km
Alnus (alder)	250 – 300 km
Quercus (oak)	about 1 km

Entomophilous (pollen is carried by insects) – linden, chestnut, but mostly species in the undergrowth – bird cherry, currant, mountain ash, cowberry, etc. These plants have sticky pollen and pistils, large perianths, and long flowering. The pollen grains of entomophilous plants are large, sticky, exine with a noticeable sculpture, i.e. the presence of spines, needles, protrusions. Pollen is produced in small quantities in entomophilous plants. Many entomophilous species bloom after the leaves open (linden, bird cherry, apple, cherry, honeysuckle, lilac).

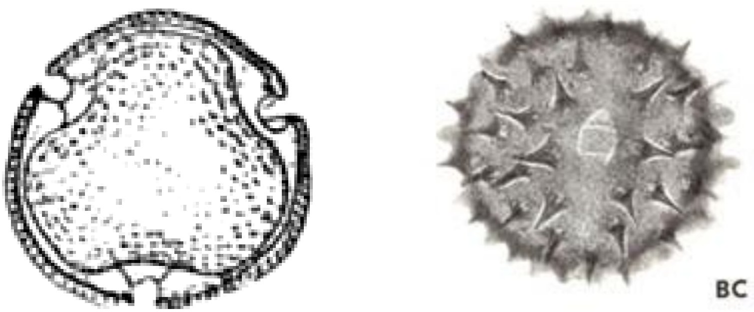

Figure 2. **Pollen structure of entomophilous plants**
(1 – linden; 2 – sunflower)

Task 1. Write down what indicators are taken into account when determining pollen viability. Describe the object of research to determine the viability of pollen.

Pollen grains can be three-, four-, five-, and multi-lobed; round, etc. Pollen grains have 2 shells – outer (exine) and inner (intine). On the surface of the grains, there are pores and furrows (from 1 to 30) – the exit points of pollen tubes. The size of pollen grains ranges from 10 micrometres (microns) or less to 100–200 microns (1 micron – 0,001 mm). The shape, size, structure of pollen grains and the characteristic structure of the exine are hereditary permanent features of the species.

Scots pine. Pollen grains consist of a body and two air sacs, which are shifted to the inner side of the body. The air sacs have a regular hemispherical shape. The line of attachment of the bags to the body is less than their diameter. The exine of the body and air sacs is granular. Grains are large, 60–105 µm long, body height 30–60 µm, height of air sacs 24–50 µm. Pollen is collected in May during the flowering of male cones

(2–3 days). Yellow pine cones are collected before the pollen begins to crumble, picking off the unopened inflorescences. Then they are dried (2–3 days) indoors so that the pollen is not spread by the wind. Then the pollen is poured out of the cones and sifted through a thick sieve.

Common spruce. Pollen grains are oval. The body is larger than the air sacs. The length of the grains is 60–120 µm, the height of the body is 40–80 µm, and the height of the air sacs is 30–70 µm.

European larch. A characteristic feature is the absence of air sacs, furrows and pores. The grain is large, 75–96 µm in diameter. The exine is thin, smooth, two-layered. The intine is very thick, about three times thicker than the exine. When pollen tubes exit, pollen bursts anywhere.

The size of hardwood pollen is generally much smaller than that of coniferous pollen grains.

Balsam poplar. Pollen grains are rounded, some are irregular. There are no pores. The exine is very thin, sometimes completely smooth. Body diameter is 24–38 µm.

The birch is hanging. Pollen grains have triangular–rounded contours, the number of pores is three. The exine is smooth. Body diameter is 15–25 µm.

Willow. Pollen grains are ellipsoidal and strongly elongated when dry. When swollen, they are almost rounded. There are three furrows located meridially. There are no pores. The exine is reticulate-cellular. Body diameter is 15–28 µm.

After pollination, pollen germinates and forms a pollen tube (*Fig. 3*). The process of pollen germination varies from tree to tree and from shrub to shrub: in white acacia it takes 3 hours, in birch – 3 weeks, in oak – 1,5 months, in pine – about a year, and so on.

Figure 3. **Germination of pollen grains.**

In nature, seeds can be formed without fertilisation: in naked-seeded species, *parthenospermia* (seeds without an embryo), in covered-seeded species, *parthenocarpia* (seedless fruits). In forestry, parthenocarpy can sometimes cause enormous damage (birch, linden, willow, maple). Ash maple sometimes produces up to 100 % empty seeds.

The viability of pollen is determined before pollination, which is especially important if the pollen has been stored for a long time or collected elsewhere. Methods for determining pollen viability in woody plant breeding include germination of pollen on artificial nutrient medium, observation of pollen germination directly on pistil stigmas, and staining methods for freshly collected pollen.

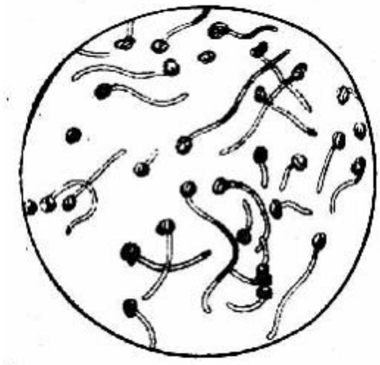

Figure 4. **Germination of pollen grains in sucrose solution (under the**

Task 2. Write down the process of preparing a chamber for germination in a «hanging drop». Describe the process of sowing pollen for germination. Draw a schematic drawing of the «hanging drop» preparation.

<u>Preparing the chamber for germination in a hanging drop.</u> Each student receives a slide with three chambers for germination. Before starting the experiment, make sure that the chamber is properly prepared: the paraffin wax must be firmly adhered to the slide and the top surface must be flat, otherwise the hanging droplet enclosed in the chamber may dry out. Slides should be cleanly washed and degreased in alcohol.

Use a spatula to apply a layer of petroleum jelly to the edges of the roofing glass so that a continuous mound is formed with a width and height of approximately 2 mm. After that, place a small drop of liquid, which is the medium for pollen germination, in the middle of the roof glass. The drop should be placed in the centre of the glass, not spread over its surface, and form a convex spherical surface.

Each student prepares three cover slips. On two of the glasses, apply the optimal medium for germination of the pollen of a given species, and on the third glass – a drop of distilled water. Add a stimulant to one of the drops of the optimal medium (when working with oak pollen, for example, place a small piece of an oak stigma). Place the glasses prepared in this way on black paper (so that the well-sown pollen is clearly visible against the black background) and sow the pollen.

Sowing pollen. To sow, collect a small amount of pollen on the tip of a dissecting needle. Then, gently shake the needle over the drop of liquid, and thus apply the pollen to the surface of the drop. It is important that the pollen grains are deposited on the surface of the droplet and are not in the middle of the droplet. This requirement is due to the fact that pollen needs oxygen to germinate. Pollen grains that lie on the surface of the droplet, on its molecular film, do not sink into the droplet, so during germination, they receive oxygen from the surrounding air. If you dip a needle with pollen into a drop, the pollen grains will fall into the drop and be isolated from the oxygen in the air.

For each drop, 100–150 seeds should be sown, which is achieved by exercise. If the seeding is too dense, it will be difficult to count the number of germinated seeds and determine the germination percentage. With a thin seeding, the number of grains will be too small to calculate the germination percentage. In addition, single pollen grains germinate less well than in mass sowing. Since the coverslips on which the sowing is done are placed on black paper, the pollen sowing can be monitored either macroscopically (with a binocular) or with a magnifying glass.

Preparation of the preparation. After sowing pollen, carefully take the glass slides with the drops on them by the edges with two fingers of the left hand (thumb and forefinger) and then quickly turn them over with the right hand so that the drops are on the lower surface of the glass. Then place the cover glass on the camera, with the drop in the centre of the camera. Press the cover glass lightly against the chamber surface at the edges; the petroleum jelly that has been applied to the edges of the cover glass should firmly bond the glass to the chamber.

Then you need to make sure that the glass is tightly fitted to the chamber and that there are no free gaps through which air can enter the chamber. Otherwise, a drop that is not isolated from the outside air in the chamber may dry out during the experiment, the concentration of the solution in it will change and the pollen will not germinate.

After all three chambers are covered with a cover slip, the preparations must be examined under a microscope. And if it turns out that the preparations are poorly made, they need to be reworked.

A properly made preparation has a sharply defined drop in the middle of the cover slide that has not blurred, with about 100 pollen grains on the surface. Put well-made preparations in a thermostat (at a temperature of about 25 °C) until the next day.

Task 3. Find out the features of viewing and recording germinated pollen. Fill in the table to record the results of the process of germination of pollen grains.

Viewing preparations and counting germinated pollen grains. With a high pollen viability, the first stages of germination and the emergence of pollen tubes can be observed as early as 3–4 hours after the pollen has been placed for germination. The final results are visible after about 12–24 hours. In the context of laboratory classes, this means that the viewing of the prepared preparations and counting of germinated pollen is carried out the day after the start of the experiment.

First, the general picture of pollen germination in all three preparations made by each student should be viewed under the microscope, and then the number of germinated and ungerminated pollen should be counted. Counts should be made from each camera in five fields of view. Then, from these fields of view, count the total of all pollen grains in the chamber and the number of germinated grains. Calculate the percentage of germinated grains from the total.

In addition to counting the germinated grains in each preparation, determine the average length of the pollen tubes. It can be determined by measuring with an eyepiece micrometer or by eye. In the latter case, express the length of the tubes in terms of the diameters (d) of the pollen grains.

In addition, several pollen grains with pollen tubes are sketched in the notebook.

The description of the experiment should be in the following form:

Pollen __________ Date of the experiment start _____________________
(species name)
When the pollen was collected ___________________________________
How pollen was stored before the experiment _______________________
____
Microscope magnification ______________________________________

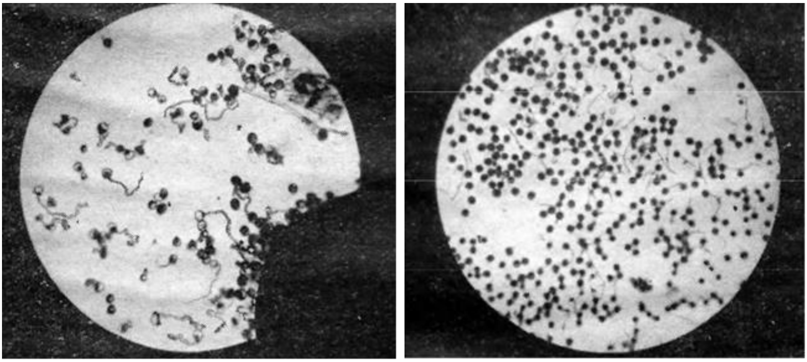

Figure 5. **Oak pollen germinating under a microscope.**

Control questions:

1. What kind of forest species can be pollinated?
2. What shape can be pollen grains of conifers?
3. What form can be pollen grains of deciduous crops?
4. Preparation of a chamber for germination in a hanging drop.

PRACTICAL WORK NO. 9

Topic: METHODS OF ARTIFICIAL POLLINATION

Aims: to get acquainted with the procedure of hybridisation of woody plants.

Material and equipment: cut branches of forest crops, insulating bags, tweezers, scissors, and a workbook.

Artificial or controlled pollination is the artificial transfer of pollen from the paternal form of a hybrid to the pistil of the maternal form for the crossing procedure.

It includes a number of sequential operations:

- selection of parental forms for crossing;
- isolation of female flowers;
- pollen production;
- pollination;
- removal of insulating bags;
- strengthening of fruit insulation bags;
- collection of cones, fruits and hybrid seeds.

Selection of parental forms for crossing**.** Parental forms for hybridisation are selected primarily by morphotype, growth rate or other economically valuable traits, depending on the breeding goal. The principles of pair selection for crossing fruit plants were developed by I.V. Michurin. Their main provisions also apply to forest species:

1. When crossing local varieties with forms that grew in other soil and climatic zones, hybrids have more features of the local parental form, as the latter are more adapted to local conditions. Therefore, I.V. Michurin recommended taking species (or varieties) distant from the place of growth as initial parental pairs and crossing them.

2. The age of the parent plants must be taken into account. Thus, a more «adult» parental form in age transmits its properties better than younger and more plastic plants. If you cross young seedlings, their hybrid offspring will be better adapted to local soil and climatic conditions.

3. When crossing, in addition to the age of the parental forms, the health of the plants should also be taken into account. Strong, healthy plants that are crossed with weak or underdeveloped plants will pass on their properties to the offspring to a greater extent. This is especially true when strong, healthy plants are used as mother plants.

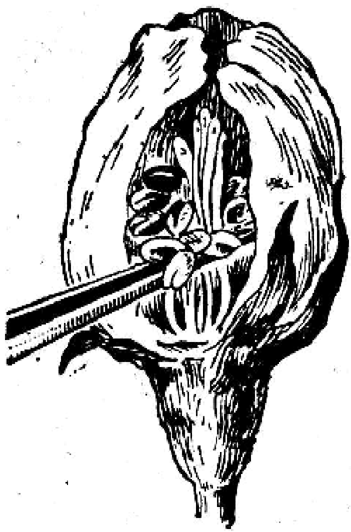

Figure 1. **Castration of a bisexual flower with tweezers through a hole in the bud.**

4. For a more targeted hybridisation, it is necessary to know the characteristics of the original varieties, skilfully select and combine them during crossing. For example, if you want to obtain large-flowered varieties, you need to select plants with large flowers as parental forms. If you use small-flowered plants as the starting forms, the vast majority of seedlings will have small flowers.

5. When crossing, you need to pay special attention to the characteristics of the mother plant, as it always transfers its properties to the hybrid more fully.

6. With distant hybridisation, combinations may appear that are not found in the parental generation.

Objectives. Study and write up the progress of artificial pollination.

Isolation of female generative organs.

Female flowers should be isolated before flowering to prevent natural pollination. Preparation of mother trees for pollination in wind-pollinated dioecious plants consists of removing male inflorescences (e.g. male earrings in birch trees and microstrobiles in conifers). In dioecious plants, spatial isolation is possible.

In bisexual flowers, castration is first carried out: stamens are removed at the bud stage (they are plucked with tweezers, damaged or treated with spermicidal chemicals).

In plants with relatively small flowers, castration is carried out with the perianth removed, which technically facilitates the procedure.

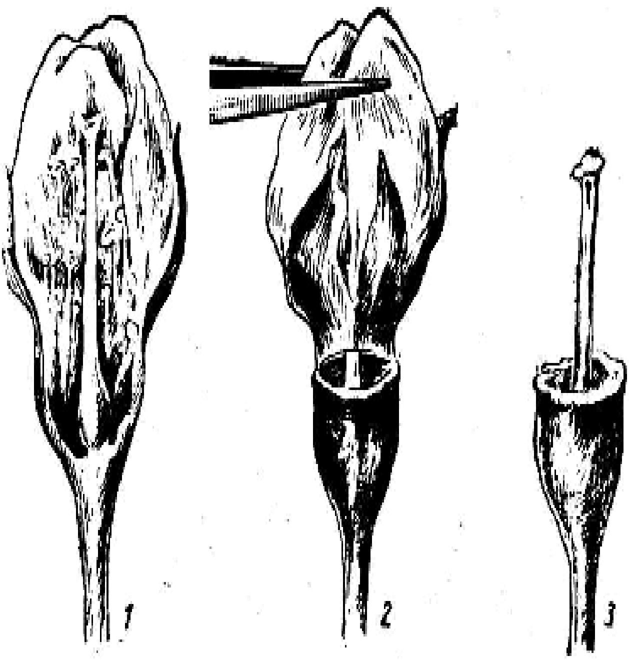

Figure 2. **Castration of the flower with removal of the perianth.**

Bags made of transparent plastic film or thick paper can be used as insulators. Insulating bags should be impervious to wind and water, light in colour to avoid overheating. The transparency of the insulator provides an opportunity to observe the condition of female flowers and economically consume pollen introduced under the insulator.

It is undesirable for the inflorescence or flower to come into contact with the insulating bag, as necrosis (tissue death) may occur. Gauze bags are used to isolate flowers of entomophilous plants.

The female flowers in the isolators are monitored. And when a female flower is able to accept pollen, artificial pollination is carried out.

Obtaining pollen. Pollen harvesting begins when individual anthers begin to burst on the illuminated parts of the crowns. Male inflorescences are collected in paper bags and left for several hours. When the pollen spills out of most anthers onto the paper, the pollen is cleaned of impurities and poured into dry flasks with labels. Pollen viability is determined in the laboratory using special methods. Effective crossing results can only be achieved when pollen viability is at least 50 %.

Pollination. After studying the biology of flowering of tree species and making sure that the pollen is viable, artificial pollination is started. Controlled crossing is usually carried out during the period of natural pollen maturation, when the susceptibility of female flowers to pollination is not in doubt.

Pollination is carried out in dry, calm weather, as wet pollen loses its viability, in addition, it sticks to wet pollination devices. Artificial pollination is repeated 2–3 times without removing the insulators, but only opening its upper part or piercing the bag with a syringe or pipette, and sealing the hole with electrical tape.

Immediately after pollination, labels indicating the male parent plant and brightly coloured labels are attached under each insulating bag so that branches with pollinated flowers can be found after removing the insulating bags. Remove the insulators after flowering is over.

The next steps in the work will be to *remove the insulation bags* and *fix the fruit insulators*. Fruit bags are gauze bags designed to protect developing fruits (cones) from damage by wind, insect pests and rodents. Later, the development of hybrid fruits and cones is monitored.

Harvesting cones and fruits. The collected hybrid seeds are stored and subsequently sown as is customary in silvicultural practice. Special attention is paid to the quality of work, labelling and hybrid selection. Controlled pollination can also be carried out indoors (greenhouse, sunroom).

Task 2: Conduct artificial pollination on cut linden branches.

The procedure for hybridisation in linden. In the trees selected for crossing, only the female flowers are left in the inflorescence, and gauze bags are placed over the entire branch because linden is an insect-pollinated tree. To harvest pollen, cut off the inflorescences of the blooming flowers, pluck out the ripe anthers with tweezers and spread them on white smooth paper. After a day, when the pollen spills out of the anthers, it is carefully swept away with a brush into a jar. Linden pollen is dry, powdery, and remains viable for 7–10 days in room conditions. For longer storage, it is stored in a low temperature desiccator. It is best germinated in a 10 % sugar solution. During pollination, pollen is applied to the pistils of flowers with a small brush. Every other day, pollination is repeated. Insulator bags are not removed until the seeds are ripe. When they are ripe, they are counted, measured and weighed. Then they are immediately sown into well–prepared soil without drying out.

Control questions:

1. What is artificial pollination?
2. Isolation of female generative organs.
3. How are seeds of cones and fruits collected?

PRACTICAL WORK №10

Topic: **PHENOLOGICAL OBSERVATIONS**

Aims: To learn how to conduct and record phenological observations of breeding material for comprehensive study and evaluation.

Materials and equipment: 4x or 7x magnifying glasses, workbook. Plants selected as objects of observation should be marked with labels tied to the branches, which can be wooden or metal with a serial number. You can also place a post or wooden label near the plant.

As objects for work, individual plants used as breeding material are selected (e.g., selected and selected plus trees, specimens taken as parent trees during crosses) and groups of plants (e.g., selected and selected plus trees, such as breeding specimens in nurseries or taken on plantations, offspring of plus trees, or selected clones of any breed that reproduces vegetatively).

For a comprehensive study and evaluation of the breeding material, it is necessary to conduct phenological observations, which reveal such important biological features from the point of view of plant breeding as the length of the growing season, the duration of certain phases of growth and development, the time of the beginning of the growing season, flowering and ripening of fruits and seeds, the setting of apical buds, shoot formation, the time of leaf fall and the end of the growing season.

The data collected during phenological observations in conjunction with meteorological factors (temperature, precipitation, etc.) provide an insight into the bio-ecological properties of plants and their relationship to natural conditions. All this is necessary for the evaluation of breeding material.

Plants that are selected as objects for phenological observations can be of different ages and grow in a wide variety of conditions.

Task 1: Write down the reasons for the expediency of conducting phenological observations of plant breeding material. Describe the methods of flowering and fruiting assessment used in forestry breeding.

Before starting the observations, each object must be described, and the observer's route through the objects must be designed in such a way as to prevent unnecessary passage and cover the largest number of objects in the shortest possible time.

Task 2: Write down the stages of development and growth of woody plants that are taken into account in phenological observations. Create a programme of phenological observations. Create a table for conducting phenological studies to fill in the field journal.

The following phases of plant development and growth are noted:

1. *Swelling of the buds.* The kidney scales begin to diverge and have diverge so that more or less light stripes or corners are visible between them.
2. *Budding of the kidneys*. The bud scales have spread so far that the tips of young leaves are visible from the half-open top.
3. *Leaf unfolding*. Shoots with underdeveloped leaves have emerged from the bud; leaf blades are small, wrinkled, and gradually straighten.
4. *Leaf emergence.* In most leaves, the leaf blades have turned completely around and have taken on normal dimensions.
5. *The end of shoot growth.* Shoot growth in length has ended, and the apical bud is laid at the top. In species that produce two or more

consecutive shoots in one growing season, the date of the second shoots and the end of their growth is noted.

6. *The appearance of flower buds and inflorescences*. In some species, this phase occurs before the leaves appear (alder, willow, some poplars and willows, ash maple, dogwood, and others); in other species, this phase coincides with leaf opening (oaks, birch, walnuts); in some species of maple, linden, white acacia, and other species, inflorescences appear much later than leaves. The appearance of buds and inflorescences as soon as they can be seen is also shown.

7. *Flowering.* Full formation and opening of flowers is observed. For species with bisexual flowers, the formation of male and female flowers is indicated separately. For wind-pollinated species, the beginning and end of pollen shedding is determined; the beginning is the moment when the first anthers are detected that have burst, and the end is when all anthers burst and pollen is shed. The end of flowering is characterised by perianth shedding (in species with perianths) or modification of the stigma (its wilting or drying out, accompanied by a change in colour).

8. *Fruit ripening*. The fruit is fully ripened, acquiring its normal size and colour, which is typical for mature fruits of this species. In some species (pine, cedar), fruit ripening occurs in the second year after flowering. The beginning of ripening, when the first sufficiently mature fruits are found, and mass ripening are also indicated. For species whose fruits fall off as they ripen (e.g., oak acorns), the first ripening of sufficiently ripe fruits is considered the beginning of ripening, and mass ripening is considered when most of the fruits have already fallen off.

9. *Seed and fruit fall*. It is noted for species in which ripe fruits with sufficiently ripe seeds continue to hang on the tree for some time. It indicates the beginning of the falling process when the first seeds or fruits that have fallen are detected and the end of it when all seeds and fruits have fallen.

10. *Autumn leaf colour*. The day on which the first leaves that have changed colour (yellowing or reddening of the leaf blades) are detected is marked. However, autumn colour change should not be confused with occasional yellowing of the leaves as a result of drought or damage. The full autumn colour change is determined when all the leaves have completely turned this colour.

11. *Leaf fall*. It begins when the first fallen leaves are found and ends when all the leaves have fallen.

Task 3: Assess the degree of flowering and fruiting using the biological method of M.S. Nesterov

In addition to these phenological phases, all cases of any damage caused by frost, drought, entomological pests and diseases should be noted during the observations.

The general programme of phenological observations may be changed in accordance with the peculiarities of the phenology of a particular breed, the age of the experimental objects and their condition.

During the phenological observations of flowering and fruit formation, it is necessary to obtain a quantitative description of these phenomena.

Assessment of the degree of flowering and fruiting can be carried out according to the scale of V.G. Kapper, or using the modified biological method of M.S. Nesterov.

V.G. Kepper's scale

Score 0 – fruit and seed failure, lack of flowering.

Score 1 – very poor yield, seeds and fruits are observed in very small quantities and only on single plants.

Score 2 – poor yield, fruits and seeds are present in small quantities on many plants.

Score 3 – medium yield, fruits and seeds are present in medium quantities on many plants.

Score 4 – good yield, good fruiting on most plants.

Score 5 – very good harvest, good fruiting on most plants.

Biological method of flowering and fruiting assessment according to Nesterov.

On branches cut from plants, the number of flowers or fruits is counted and this number is assigned to a unit of branch length (metr-branch). The length of the branch is determined by direct measurements, and not only its axial part, but also the length of all branches and shoots are determined.

A modified biological method.

Since the length of branches is not a sufficiently defined indicator, which depends on subjective reasons and growth in the length of shoots, the characterization of fruiting by the previous method may not be entirely objective. A more objective indicator of the degree of flowering and fruiting in species that form reproductive organs on annual shoots will be the number of flowers and fruits per 100 shoots of young shoots. This method makes it possible to assess the degree of flowering and fruiting of woody plants quite objectively.

Phenological observations should be carried out as often as possible, especially during periods when the phenophases change each other. Such times can be spring and the flowering time of a particular species. Only with sufficiently frequent observations, sometimes daily, can the date of the onset of each phase be timely and accurately noted. If observations are carried out with long intervals, then large errors in the accuracy of determining the onset of individual phenophases can be obtained.

It is better to conduct phenological observations in the afternoon, since only in this case there will be complete confidence in the correctness of the definition of a particular phenophase.

When observing a group of plants (for example, a breeding sample), the beginning of the phase should be the time when it begins in single specimens of this sample. The end of the phase is determined by the day when all plants in this group have completed this phase.

All data from the observations are recorded in a field journal of phenological observations directly at the site of the study object. Entries in the field journal (Form 1) are made with an ordinary pencil. Corrections or inaccuracies are not allowed.

Missing the scheduled observation periods should not be allowed. The onset of such phases as bud swelling, the beginning of pollen shedding, etc. is determined using a magnifying glass.

Form 1: **Field journal of phenological observations**

<table>
<tr><td rowspan="3">No. of breeding samples</td><td colspan="8">Name of phenological phases observed</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>beginning</td><td>end</td><td>beginning</td><td>end</td><td>beginning</td><td>end</td><td>beginning</td><td>end</td></tr>
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Task 4: Draw a diagram of the phenological phases in the form of a phenospectrum. Describe the procedure for conducting phenological observations of woody plants.

The data recorded in the field diary are presented in the form of a graph called a phenospectrum for a more visual overview and analysis. In it, for each breeding sample, we set aside a horizontal strip of a certain width. Above this strip, place calendar dates on a scale.

We mark the beginning of each phase at the upper border of the bar, and the end of the phase at the lower border. With this method of graphically marking the beginning and end of phases, the lines that separate them will be placed at an angle. The shape of these trapezoids and especially the angle of the sides give a very clear idea of the pace and intensity of the growth and development processes of certain breeding samples. Each phase on the spectrum is represented by a specific symbol.

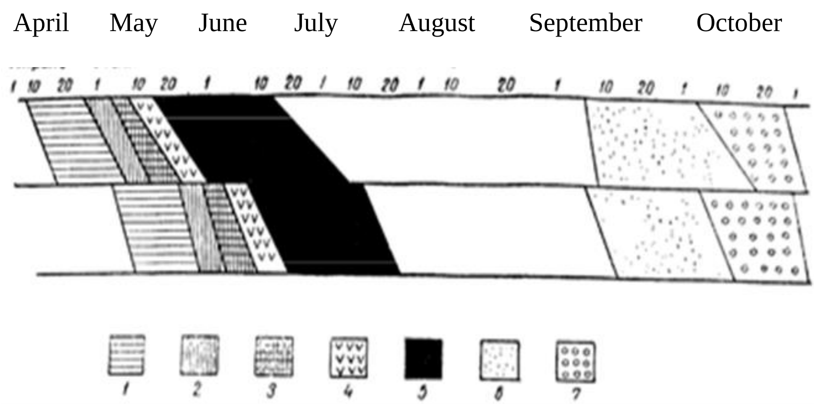

Figure 1. **Phenospectrum.**

Symbols: 1 – bud swelling; 2 – bud opening; 3 – leaf unfolding; 4 – full leaf emergence; 5 – shoot growth; 6 – autumn leaf color; 7 – leaf fall.

Control questions:

1. Name the phases of plant development and growth.
2. The essence of the biological method of evaluation of Nesterov.
3. What is the scale of V.G. Kepper?
4. How to present the information in the form of a phenomenon spectrum?

PRACTICAL WORK № 11

Topic: **SELECTION OF SEED PLUS TREES**

Objective: to master the method of selecting plus trees for high productivity and trunk quality.

Materials and equipment: altimeter, incremental drill, pole or other angle measuring tool, 20 m tape measure, 6x or 8x binoculars, 4x to 7x magnifying glass, camera, plantation tablet in which the work is being carried out, knife for stripping bark on the trunk, white and black paint, set of stencils with numbers from 0 to 10.

Trees that differ in a positive way from the mass of others in terms of growth rate, trunk and crown quality, wood quality and other important traits in forestry selection are called plus trees or plus trees.

The selection of plus trees can be carried out with different objectives depending on the purpose and geographical area of the plantation from the seeds of the selected plants. For example, to select pine trees for growth rate and wood quality, plus trees should be selected from among specimens with vigorous growth, a relatively narrow crown raised high on the trunk, thin branches with a trunk that is free of knots, slanting and other defects.

If the breeder's task is to select trees based on high resin productivity, plus trees may not be vigorous in growth, but should be characterized by a powerful, low-slung crown with thick branches and densely covered with needles.

Thus, the selected plus trees may have different characteristics depending on the task set before the breeder. Plus trees should be characterized by features that are typical for plants with vigorous growth and good trunk and crown shape, healthy, not affected by diseases, not affected by pests, without signs of dry tops, and slanting.

Highly productive (first and second class of bonita) plantations of the most important species should be selected for work. In the forest-steppe regions, these are primarily pine and oak plantations, and in other forest vegetation zones, other species depending on their economic importance. Preference should be given to plantations of natural seed origin. Plantations of artificial origin (forest crops) are less desirable, as they have less pronounced tree variability and are often the products of negative selection.

Natural seed plantations are characterized by high variability in tree traits. Trees in such plantations are well adapted to the conditions of the location, and the selection of plus trees among them in the future should lead to the improvement of this breed. In terms of age, plantations should be close to the age of maturity that is accepted in forestry for a given species in a particular forest vegetation area. This requirement is related to the fact that it is at this age that the properties of trees of interest, namely productivity, trunk and crown shape, their stability, etc., are most fully manifested. Evaluation of trees for their productivity and quality at this age should give reliable results.

Selection of plus trees in very old stands is impractical, as they may contain biologically old trees and those that are naturally dying. In younger stands, the selection of plus trees is possible, but the results are less reliable. In the life of plantations that are at the age of the pole, there is an intense differentiation of trees in terms of growth strength, signs of resistance to adverse environmental factors and forest pests.

The plantations should be characterized by a fairly high density. In exceptional cases, less complete stands may be used for selection if low completeness is the result of recent intensive thinning. Sometimes among the trees of a thinned stand you can find specimens characterized by a good trunk shape, without knots, with a narrow, raised crown on the trunk. Trees that have grown in thinned plantations and that differ in such characteristics are of particular importance and should be selected as plus trees. With a high degree of probability, it can be said that such specimens are distinguished by hereditary features that are inherent in the best plus trees.

The conditions in which a particular plantation grows, which is selected as an object for the selection of plus trees, should be characterized by significant uniformity throughout the plantation. Unsuitable stands for the selection of plus trees are those characterized by heterogeneity of location conditions, for example, pine stands on sandy drifts, or oak stands on slopes with different slopes in different parts. In such stands, trees that differ in height may have appeared because they grew in slightly better conditions than their neighbors, which were in worse conditions.

Task 1: To familiarize yourself with the reasons for the selection of plus trees.

Task 2: Find out the progress of the work on the selection of fast-growing forms.

We select plus trees based on the following main criteria: first, we select trees by their growth rate, then by their condition, trunk and crown shape, and degree of fertility. Only those trees that meet all of these requirements can be classified as plus trees.

Selection by growth rate. In the plantations planned for the selection of plus trees, determine the average height and average diameter. It is carried out by conventional taxation methods: by recalculation taxation, gas measurement or with the help of a taxator.

Determination of the average height and average diameter is necessary for the objective selection of the fastest growing trees in a particular stand. The regularities of the structure of stands of the same age, established by the theory of forest taxation, allow us to select from the total number of trees those that are really the most outstanding in terms of their growth in this stand. For pine stands of the first class of bonita, it is known that the largest tree in the stand is 10–15% taller than the average tree. If you know this pattern, you can determine what tree height you should look for in such plantations in order to select the fastest growing specimens.

The largest tree in a pine forest of the first class exceeds the average tree by 70 % in diameter. This means that knowing the diameter of the average tree, it is possible to determine the diameter of the largest tree using these data. Thus, the breeder's task is to identify among the trees in the plantation specimens that are close in size to the size of the largest trees.

To facilitate the identification of the largest trees in a particular stand, you can use the table below, which shows the diameter of tree trunks depending on the average diameter. Knowing the average diameter of the trees in the stand, you can use this table to determine the size of the largest trees, and thus the fastest growing trees.

Having found trees of the appropriate size in height and diameter in the plantation, having rejected among them trees with obviously negative signs, diseased trees and trees with a large number of pests, we proceed to determine the growth rate of the selected trees. Growth rates in height and diameter should be higher than the average tree in the stand.

Table 1: **Maximum diameters of tree trunks depending on average diameters** (according to A.V. Tyurin)

Diameters of trees in plantations, cm									
average	maximum	average	maximum	average	maximum	average	maximum	average	maximum
10	16	20	34	30	52	40	68	50	85
11	18	21	35	31	54	41	70	51	86
12	20	22	36	32	56	42	72	52	87
13	22	23	38	33	57	43	73	53	88
14	24	24	40	34	58	44	74	54	91
15	26	25	42	35	59	45	76	55	93
16	27	26	44	36	60	46	78	56	95
17	28	27	46	37	62	47	79	57	97
18	30	28	48	38	64	48	81	58	99
19	32	29	50	39	66	49	83	59	101

Height growth is estimated by eye (using powerful binoculars). The line of the apical shoot of the last years of the tree's life – this year and the two previous years – is determined. For pine, this determination is easy, as it is made outside the shoots, which are marked by whorls of lateral branches. For oak and other hardwoods, the length of this year's shoots can be determined on the trees. This year's diameter growth is determined at a height of 1,5 meters using a growth drill.

Selection by condition. Trees selected for growth should be evaluated in terms of their condition and health. There are two reasons for this. On the one hand, specimens that are resistant to damage are selected. On the other hand, the quality of seeds and seed offspring of a tree is affected by the physiological state of the mother organism. A sick, infected and damaged tree cannot be expected to produce good quality seed material. Therefore, trees with obvious mechanical damage, hollows, dry tops, signs of branch death along the periphery of the crown, frost cracks, bark heating, fruiting bodies of fungi on the trunk and roots, as well as signs of damage by secondary pests (bark beetles, whisker beetles, etc.) should be rejected.

Task 3: Write up an algorithm for selecting trees by trunk and crown quality.

Selection by trunk and crown quality. As plus trees, it is necessary to select trees that have both good trunk and crown characteristics. In this respect, plus trees should be characterized by the following main features: straight trunk, no eccentricity, good trunk with no knots, well-developed symmetrical, uniform and compact crown with a pointed top. The length and thickness of the lateral branches, the angle of deviation and the type of branching, and the nature of the crown are also important.

These characteristics can vary greatly for each species and for different habitats, so it is almost impossible to give general indicators for tree selection. These should be established on site, but the following general guidelines can be used for initial orientation:

Trunk shape. The trunk should be straight along its entire length to the top of the tree. The straightness is assessed visually, the tree is examined from at least two recognizably perpendicular sides. The absence of eccentricity is also determined visually. The advantage is given to those trees that have a well-defined trunk to the very top, that is, that have a monopodial type of branching, no forks, etc.

Oak and other hardwoods often lose this trunk shape in their mature state and acquire a pseudo-dichotomous stem branching pattern. We consider such trees to be less desirable than those that have retained a monopodial branching pattern and a straight stem to the top.

The nature of branching and the degree to which the trunk is free of knots. The presence of thick and long branches that extend from the trunk at an acute angle is assessed as a sign that is less valuable than the presence of thin and short branches that extend from the trunk at a close to straight angle. Such trees have a better process of clearing the trunk of knots. The degree of trunk clearing is determined by determining the height at which the lowest dead branches and lower living branches are located along the trunk.

In this way, three zones of the trunk are identified:

1) completely free of knots;

2) the zone where the process of clearing the trunk from knots takes place;

3) the zone of the living crown of the tree.

Trees with the largest length of the first zone and the smallest length of the second zone are preferred during selection. The length of these zones is expressed in absolute values (meters) and the ratio of the zone length to the total height of the tree.

When selecting plus trees in oak, we pay attention to the absence of “fatty” and water shoots. Trees with a secondary crown formed from perennial “fatty” growth are rejected.

The nature of the tree crown. The length of the living crown should be no more than 1/3 to 1/4 of the trunk length. A large crown length indicates poor trunk cleaning from knots. At the same time, a crown that is too short may indicate poor tree health. The crown should be developed evenly in all directions and be symmetrical. Trees with a smaller crown projection area have an advantage, all other things being equal.

The shape of the crown is also an advantage during selection. Trees of different species at different ages will have different shapes. As a rule, young trees have a more pointed crown, closer to a cone in shape, while large trees usually have spherical or umbrella-shaped crowns. A pointed crown shape indicates vigorous growth of the tree in height and good growth of the main shoot. A blunted crown shape, umbrella-shaped or hemisphere-like, indicates that the growth of the main axis of the tree stops, and the lateral axes catch up with the growth rate of the main shoot. This indicates the physiological old age of the tree. Therefore, among trees of the same age of the same species, specimens with more pointed crowns are valued higher than trees with blunt, umbrella-shaped or spherical crowns.

The nature of the tree's crown is of secondary importance for assessing the technical qualities of the wood. Therefore, we take into account the pattern, color, thickness, size, and direction of crown cracks. We pay special attention to the direction of the cracks, as they can easily identify such a negative characteristic as warpage. This trait is hereditary. Spiraling bark cracks indicate a splayed bark and such a specimen cannot be selected for plus trees.

For some species, it is important to preserve a smooth bark to a considerable age, which indicates good qualities and properties of the wood. Birch trees, which belong to the Karelian form with valuable and beautiful wood, have a tuberous trunk surface and thick, darkly colored cracked bark. The valuable red pine is characterized by lamellar bark, while the less valuable larch has scaly bark.

Task 4: Identify the features of tree selection by fruiting degree. *Selection of trees according to the degree of fruiting.* Trees selected as plus trees should be characterized by good fertility. Specimens that have all the good features but bear little fruit lose their value as plus trees, which are intended to produce offspring from them. In addition, good fruiting indicates the tree's viability and resistance to habitat conditions.

Tree fruiting can be assessed by the so-called biological method of N.S. Nesterov, the essence of which is to determine the number of fruits per unit length of branches. When assessing the fruiting of an oak tree, a good way is to determine the percentage of shoots that bear fruit relative to all shoots of a given year and to determine the number of female flowers, ovaries or acorns per 100 shoots of a given year.

To assess the fruiting of a single tree, the Kapper fruiting scale cannot be used, since the indicators of this scale refer to the assessment of the fruiting of the entire stand, not individual trees.

If the work is carried out at a time of year when there is no fruiting, we pay attention to old cones or acorns that have fallen or sel-seeding. Their presence indicates that the tree is bearing fruit.

In addition to the quantitative side of fruiting, we also take into account the qualitative side. As a rule, large fruits and seeds provide better sowing qualities and should be evaluated more highly than small ones. Good germination and germination energy of fruits and seeds harvested from the same tree are also important.

Task 5: Create a general scheme for selecting plus trees from the first to the last stage.

We mark the selected trees in the field, and their location is filmed and geodetic tied to any landmarks. In addition, we fill out a passport for each tree. It is desirable that the tree is photographed.

Trees are marked in nature at a height of 1,3–1,5 meters from the soil surface. To do this, we use a special knife to peel off the bark around the entire trunk about 10 cm wide. We clean the trunk carefully so as not to damage the living part of the bark. On the cleaned strip, apply a 5–6 cm wide white band with oil paint. On the southern side of the tree, we use a stencil to mark the tree's serial number with black paint.

The tree is geodesically tied to the nearest landmark using a pole or any geodesic tool and a measuring tape or tape measure. Such a landmark in the forest can be a quarter post. We mark the binding on the block tablet and on the diagram, which is placed in the tree passport.

We also determine the relative position of the group of trees surrounding the selected plus tree. On the schematic plan, we mark not only the position of these trunks, their belonging to a certain species, but also show the projection of their crowns. At the same time, we fill out a passport for the selected plus tree in a certain form.

The photo should show the entire tree from the ground to the top.

Control questions:

1. Define the term «plus tree».
2. Describe the environmental conditions and general indicators that should be taken into account when selecting plus trees.
3. Describe the process of selection by plant condition.

PRACTICAL WORK № 12

Topic: **GENETIC EVALUATION OF PLUS TREES BY SEED PROGENY. ORGANIZATION OF A PERMANENT FOREST SEED BASE**

Objective: To get acquainted with the main directions of seed production and with the organization of a permanent and temporary seed base.

Material and equipment: table material, notebook, pen.

In order to create new forms of woody plants, artificial selection is used, which, like natural selection, is based on the heredity and variability of plant organisms. For artificial selection, plants that have evolved as a result of natural selection over thousands of years are usually used. In natural populations or other plantations, economically valuable individuals of woody plants are selected based on phenotypic traits (decorativeness, productivity, yield, resistance, etc.), which are the starting point for further selection work on pairing, crossing and hybridization.

Provision of seeds of appropriate assortment and quality for generative propagation of woody plants is possible if there is a permanent and temporary seed base.

Task 1. Summarize and study the main criteria for organizing a permanent seed base of woody plants.

Organization of a permanent seed base of woody plants includes:

– conducting a breeding inventory of green spaces for various purposes in order to identify and select the most decorative phenotype, resistant woody plants and coenoses with high generative capacity;

– preservation of the genetic fund through the creation of archival and mother plantations, collection plots, genetic banks of tree and plantation seeds;

– genetic evaluation of local and introduced populations in population and ecological cultures, selection of new forms and varieties;

– genetic evaluation of clones and seed progeny, selected ornamental forms and varieties of woody plants;

– creation of permanent seed plantations of different origin (seed and vegetative);

– establishment and formation of seed and collection plots.

In seed production, there are two directions of transfer to a genetic and selection basis: **population and plantation.**

The population direction involves the use of the best plantations, mainly of natural origin, which are selected during mass selection, for seed harvesting. For reproduction in optimal habitat conditions, seeds are taken both directly from the best plantations and from previously allocated permanent seed plots.

The plantation approach is based on the use of material from plus trees propagated vegetatively or by seeds, and seed plantations are created from grafted seedlings or seed offspring of plus trees, which are called clonal in the first case and family in the second.

Both approaches have their advantages and disadvantages. The advantage of the population approach is that in the case of seed propagation, the genetic diversity of species adapted to local conditions is preserved and the population variability of future plantations is maintained.

Plantation breeding opens up wide opportunities for breeding, and their relatively low genetic diversity can be compensated for by increasing the number of clones or seed progeny on the plantation.

One of the main factors that determines the success of the use of planting material is the geographical origin of the seeds. The use of seeds from other areas without taking into account their hereditary properties leads to the formation of biologically unstable and low-quality green spaces.

The geographical origin and habitat conditions of mother trees and plantations, if they are exposed to plant organisms for a sufficiently long time, affect the hereditary properties of seeds. Therefore, when using seeds of woody plants of non-local origin for harvesting, the requirements of seed zoning should be followed, which regulates the permissible directions and distances of movement of seeds of a particular plant species, taking into account their geographical and edaphic origin.

The theoretical basis of seed zoning is that trees and plantations grown from locally sourced seeds grow better than those created from seeds collected in remote areas. Therefore, when harvesting seeds, preference should be given to seeds that are harvested within the territory.

In view of this, to ensure regular receipt of seeds with valuable hereditary properties and high sowing quality, seed bases of woody plants are created, the organization of which provides for: 1) district-b-district breeding evaluation of plantations and trees with selection of the best (plus) trees and plantations; 2) preservation of the breeding stock by creating collection planting-archives of clones; 3) creation of seed plantations of seed and vegetative origin. The known provisions on the variability and heritability of species indicate the need to give preference to seeds collected from trees of better growth, higher decorativeness and biological stability.

In order to create biologically sustainable ornamental plantings, it is necessary to use seeds of a certain geographical origin with the best hereditary properties.

Task 2. Take notes and study the main categories of seeds of woody plants.

Seeds of woody plants are divided into six categories based on their breeding value, taking into account their hereditary properties, origin and sowing quality: varietal, improved, normal, hybrid, elite and nonvarietal.

Varietal seeds. These include seeds that have passed state variety testing and received variety status (entered in the state register). The objects for harvesting varietal seeds are clonal seed plantations of the first and second generation, family plantations, plus plantations, and permanent seed plots. Varietal seeds are genetically the most valuable, and therefore their production and harvesting should be actively promoted.

Improved seeds. They are obtained at seed facilities created or formed on the basis of selection based on the phenotype of the best normal and plus trees with free pollination (pollinating trees are unknown). Such seeds are not subjected to progeny testing. This category includes seeds collected a) from the best (plus) trees; b) in the best (plus) plantations or seed reserves; c) on permanent seed plots established in the best normal plantations; d) on plantations created by seedlings or saplings grown from varietal seeds, as well as seeds from plus and elite trees (beech, oak, exotics, etc.); e) on first-generation clonal seed plantations and family plantations.

Normal seeds are harvested in normal plantations from trees of satisfactory economic value and sanitary condition. This category includes seeds collected: a) from permanent (except for the cases mentioned above) and temporary seed plots; b) from growing normal trees of certain coniferous and deciduous species (pine, fir, beech, oak, etc.).

Hybrid seeds are obtained by crossing different species (varieties) and ecotypes of species on special plantations, which provides a heterotic effect.

Elite seeds are produced on seed plantations by cross-pollination of vegetative offspring of elite trees (i.e. trees that have been positively evaluated for seed production and combinational ability) or by controlled pollination of elite trees.

Seed without varieties. They are collected from plantations of unknown origin and are therefore not desirable for use in green spaces.

Control questions:

1. What are permanent and temporary seed bases?
2. What are the directions of seed production in forestry?
3. What are the categories of seeds?

PRACTICAL WORK NO. 13

Topic: **CHECKING THE HEREDITARY PROPERTIES OF PLUS TREES IN OFFSPRING**

Aims: To get acquainted with the requirements necessary for the preparation of a nursery of plus-tree samples for determining their hereditary properties.

Material and equipment: containers for seed samples (bags made of cloth or thick paper of a size that can hold seeds from each plus tree);

labels with the number of the plus tree, marker, rope for marking the rows of sowing or planting, hoes for making seed furrows, shovels or Kolesov swords for planting, buckets or planting boxes, etc.; labels for installation on the breeding plantation.

Task 1: Familiarise yourself with the parameter requirements for the preparation of a nursery or plantation.

Plus trees are selected for their external, phenotypic characteristics. In order to be fully confident in the breeding value of the selected plus trees, it is necessary to check their hereditary properties. To do this, seed offspring are obtained from the plus trees and their growth patterns are studied. This study is carried out in breeding nurseries by comparing the progeny of the plus trees with the same–aged plants of the same species grown under similar conditions. The comparison should continue for several years, with a minimum period of 3 years.

Task 2. Describe the peculiarities of the process of sowing and planting of plus–tree samples and the standard (control).

Seeds are collected from the selected plus trees and prepared for sowing in a way that is appropriate for the species. In addition to the seeds from the plus trees, seed material must be available from which a parallel sowing is created for comparison with the growth of the progeny of the plus trees (this material will be referred to as «standard»).

The seed material should be carefully sorted and prepared for sowing in the same way as the seeds of the plus trees. Sowing can be carried out directly to a permanent place, or on a special breeding plantation, or in a breeding nursery. Observations of the growth of the offspring are carried out for 1–2 years, and then both experimental and standard seedlings are planted on a permanent area on a breeding plantation.

The areas of the breeding plantation and nursery should be homogeneous in terms of topography, soil conditions and soil preparation.

Seed samples taken from one plus tree should be of such a size that at least one hundred seedlings can be obtained after sowing. The number of seeds of the standard should be half the number of seeds of all samples collected from the plus trees.

The pre-collected and prepared seeds should be delivered to the sowing site in suitable containers, labelled with the number of the plus tree. The site selected for the nursery or plantation should be characterised by a flat terrain, sufficiently rich soils and favourable moisture conditions. The soil on this site should be carefully prepared in advance. If the site is out of agricultural use, and different crops were grown on different parts of it, then a levelling sowing of one crop should be carried out for one year before establishing a breeding plantation on this site.

Seed samples of plus–trees and standard are sown simultaneously; during sowing, the agrotechnics adopted for growing this species in nurseries are observed. (Depth of sowing and planting, preparation of seeds for sowing, seeding rate, etc.) On the breeding plantation (preferably when sowing seeds of such species as oak, walnuts, beech), row crops are created with the placement of seeding places at a distance of 15–20 cm from each other. The sowing is carried out so that one row of the standard is sown after two rows of the test samples. This arrangement of samples and standard allows for a comparison of the growth of each sample growing directly next to each other. In this case, the number of rows of the standard is half the number of rows of the samples under study. It is desirable that each sample occupies at least one row in the sowing. If sowing is carried out on a plantation that has long rows of seed that can accommodate several seed samples, the samples should be separated by a seeding consisting of several plants of any other breed. Preference should be given to shrubs. At the beginning of sowing, each sample is labelled with its number. In addition, several rows of the standard are sown along the edges of the plot as a protective zone.

Phenological observations are made on the sown samples and the standard (growth, number of leaves), and in autumn, the number and quality of surviving seedlings and their size are taken into account.

Task 3. Find out the progress of observations in the first year and subsequent years of growing plus trees and the standard (control).

Phenological observations in the first year consist of determining the beginning and end of emergence, the date of growth and the date of leaf fall. In the second and subsequent years, the beginning and end of budding, the end of growth and leaf fall are determined. Data on damage by winter frosts, frosts, and pests are also recorded. Phenological observations are carried out from early spring to autumn, periodically, every 2–3 days. At the time of observation, the number of plants in a particular phase is determined for each sample.

Autumn surveys are conducted after the end of growth. The accounting should be continuous, with all plants counted without exception for each sample and in all rows of the standard. The number of plants that survived at the time of the count, their total height, height growth over the year, the number of consecutive shoots (increments) – for species that produce several increments per growing season (oak), the number of leaves, and the diameter around the root collar are determined. Simultaneously with the accounting of the offspring of plus trees, the standard plants are accounted for. The standard is accounted for in such a way that for each breeding sample, the standard plants growing in the neighbouring row opposite the sample are taken for comparison.

Task 4: Write up an algorithm for recording the results of observations after growing plus trees and the standard.

The data collected as a result of the autumn survey are processed for each sample (offspring of one plus tree) and the standard series corresponding to this sample. During processing, the following are determined: mean values (M), standard deviation (± σ), standard errors (± m), coefficients of variation (C %). The data for each sample are compared with the data for the corresponding standard series by calculating the reliability of the difference using the appropriate formula for variation statistics. When reliable data are obtained that indicate that the growth of a given sample exceeds the growth of the standard, it is decided that the offspring of this plus tree is really developing well and that this tree is distinguished not only by its phenotype with favourable characteristics, but also has appropriate hereditary properties.

All data on the sown sample and the relevant standards are recorded on a special plan, the form of which is provided.

In addition to filling out these forms, a general list of all samples is prepared, in which the final data for each sample is entered: M±m for seedling height and diameter, number of leaves, and the reliability of the difference between the sample and the standard for each trait.

A sowing plan is also drawn up, indicating the location of the samples.

Tree №

I. Characteristics of the plantation

1. Forestry
2. Forestering
3. The tract
4. Quarter №, plot
5. Forest type
6. Topography of the site
7. Composition of plantations

8. Age
9. Origin.
10. Bonitet
11. Completeness
12. Average height H
13. Average diameter D

Location of the tree (scheme of reference to a permanent landmark: block pole, GPS, etc.)

____

II.Characteristics of the tree

1. Origin: seed, shoots
2. Form (early, medium, late)
3. Age ________
4. Diameter at a height of 1.3 m ______________
5. Height
6. Growth in diameter over the last 5 years _______________
7. Crown correction radii:

North _____________________

East ___________________

South _____________________

to the West __________________

8. Characteristics of the trunk shape ___________________________
9. Water shoots, their number and age __________________________
10. The presence of self–seeding under the tree crown ____________

____

11. Tree condition (no infestation) ____________________________

III. Acorn harvesting and seeding data

1. Date of collection ____
2. The person who collected ___________________________________
3. Number of acorns collected: ______ pcs.; weight ____________ g.

4. Average weight of acorns ________________________________
5. Storage of acorns _______________________________________
6. Date of sowing ____
7. Sowing location (row number) _____________________________
8. Number of stairs ________________ pcs., ________________%

Control questions:

1. How are seeds sown in a breeding nursery?
2. Tell us about the care of plants in the first year after sowing seeds?
3. Tell us about the care of plants in the second and subsequent years after sowing seeds?

PRACTICAL WORK NO. 14

Topic: SELECTION OF FAST-GROWING SEEDLINGS IN FOREST NURSERIES

Aims: To learn how to select seedlings of forest crops in nurseries for useful hereditary traits

Materials and equipment: a ruler with divisions for measuring seedling growth, plywood labels measuring 5 x 2,5 cm, painted with waterproof paint in two colours, attached to twine or soft wire to tie them to the selected seedlings.

Among mass plantings of any tree species, it is always possible to observe that individual seedlings differ significantly in their growth from the total mass. Since the soil conditions and terrain in nurseries are uniform, this difference in growth between some seedlings and others is due to the hereditary characteristics of such specimens. Therefore, selecting seedlings based on growth rate can have a good breeding effect.

Selected seedlings are used to create seed plots to produce seeds with useful hereditary traits in the future. Seedlings that grow vigorously in the first years of life tend to maintain this growth rate in the future. It is relatively rare to see cases when the growth energy of seedlings decreases over time and they are outpaced by specimens that were previously lagging behind in growth. In such cases, it is possible to use the culling of trees that have not met expectations in the future.

To select seedlings for growth rate, one- or two-year-old sowings of any tree species available in the nursery should be taken. It is desirable to perform the work on the example of the species that is the most important for the area in forestry terms. To select seedlings, choose a flat area that is in homogeneous soil conditions. Sowing rows should have a more or less uniform density of seedlings. Heavily thickened crops, as well as heavily sparse crops, are not suitable for seedling selection.

Task 1. Make a diagram-table describing the nursery. Get acquainted with the data that characterise the sowing of a tree species.

Data on the nursery should be collected according to the following scheme: its name; affiliation, location; features (permanent, temporary); conditions of the germination site (relief, soil conditions), area; species grown.

Nursery data should be collected according to the following programme: sowing date; breed; seed origin; seed harvest date; laboratory germination, germination energy; pre–sowing seed treatment; method of seed stratification and storage; soil preparation; sowing area; seed row layout; seeding rate; sowing method (manual, mechanised, with what tools or mechanisms the seeds were sown); seeding depth; field germination, seedling yield per linear metre and per unit area.

Task 2. Find out the progress of the work on identifying variation in seedling height.

To determine the differences in height variation in seedlings, measure 200–300 plants using a ruler with millimetre divisions. For measurements, choose one of the middle rows of sowing, which is characterised by a uniform density of seedlings, measurements in the selected row should not be made from the edge, but 2–3 metres away. Measure all seedlings in the row without any exception.

Process the measurement results using the methods of variation statistics. To do this, you need to draw up a variation series, calculate the average height of the seedlings (M), the standard deviation ($\pm\sigma$), the average error ($\pm m$) and the coefficient of variation (C %). These calculations are needed to determine which seedlings are to be selected.

Task 3: Indicate which seedlings are taken for further breeding work and into which two groups they are divided.

After the statistical processing of the variation series is completed, the size of the seedlings to be selected should be determined as those with the fastest growth. Such seedlings should differ significantly in height from the average. It can be assumed that this condition is met by seedlings that have reached a height equal to the mean plus twice the standard deviation ($M+2\sigma$). As is known from the theory of variation statistics, the number of variants in a row in the interval of more than $M+2\sigma$ is equal to 4–5 % of their total number. When calculating the average height of seedlings in a given sowing and the value of the standard deviation, it is necessary to determine the size of the seedlings that should be selected as fast–growing. Among them, you can select seedlings that are characterised by record growth. These will be specimens that have reached a height equal to the average height plus the triple standard deviation ($M+3\sigma$). Such seedlings will be less than 1 % of the total number, but they will be of the greatest value from the point of view of breeding.

Task 4. Describe the process of direct selection of fast-growing seedlings.

After determining the size of the seedlings to be selected, we proceed to the selection itself.

To do this, mark the values equal to $M+2\sigma$ and $M+3\sigma$ on the measuring ruler. Walking along the sowing row, mark all the seedlings whose height will be equal to or exceed these values.

Apply a ruler to the columns of seedlings and determine their height from the soil surface to the apical bud. At the same time, we take into account the number of all seedlings in the row, and those that do not meet the selection requirements. This is necessary to determine the percentage of selected seedlings in both categories.

We mark the selected seedlings with pre-made labels. Seedlings of the first category (exceeding the size of $M+3\sigma$) are marked with labels of one colour, and seedlings of the second category are marked with labels of the second colour. The serial number of the seedling is marked on the label. The label is tied in the middle of the seedling stem.

Simultaneously with labelling, the selected seedlings should be registered, which is recorded in a statement in which we note the following data about each seedling: serial number, seedling category, height in centimetres, number of leaves, seedling condition (no damage, etc.).

The selected seedlings are dug up in autumn or spring of the following year, and a seed selection plantation is created from them. For comparison purposes, a plot of ordinary, unselected seedlings taken from the same nursery seedling is created next to the selected seedlings. A similar algorithm can be used to select plants with the slowest growth, which can be used for ornamental purposes.

Task 5. Make a list of materials that should be made after the work on the selection of fast-growing seedlings.

The following materials should be collected as a result of the work carried out:

a) data on the nursery, in the form given above;

b) data on the crops from which the seedlings were selected. These data should be compiled in the order given above;

c) a list of the seedlings by height;

d) based on the results of the list, draw up a variation series indicating the accepted variants and their number. It is advisable to draw a graphical representation (in the form of a distribution curve) of the variation series on graph paper;

e) data of statistical processing of the variation series and calculated sizes of seedlings to be selected ($M+2\sigma$ and $M+3\sigma$);

f) a list of selected seedlings;

g) summary data on the number of seedlings of the first and second categories, the number of seedlings from which the fastest growing were selected, and the percentage of selected seedlings of each category from the number of all seedlings.

Control questions:

1. Why is it necessary to select seedlings for growth rate?
2. What data about the nursery is necessary to characterise the breeding material?

PRACTICAL WORK NO. 15

Topic: **REPRODUCTIVE CAPACITY AND TYPES OF FRUITS OF TREES AND SHRUBS**

Aims: To find out what is the importance of reproductive capacity of woody plants for forest breeding and to study the diversity of their fruits and seeds.

Material and equipment: tables, workbook, pen, pencil, collection of fruits and seeds of forest plants.

Reproductive capacity or the ability to generate, fruiting (seed production in the case of pinwheels) of woody plants occurs at the stage of maturity, when they become more constant and less sensitive to changes in habitat conditions. The onset of fruiting (seed production) of woody plants depends on many factors, including their nutritional conditions – mineral, water, light and air. For example, free-standing woody plants, whose roots cover a larger area and volume of soil, and whose leaves (spikes) on their crowns have more favourable conditions for photosynthesis due to better lighting, enter the period of reproductive capacity earlier and bear fruit more abundantly than trees in a forest stand. The data on the beginning of fruiting (seed production) of woody plants in plantations and individual trees are given in Table 1.

Table 1: **Age at fruiting (seed period) of woody plants, years**

Name of woody plants	Freestanding	Growing plantations
Rowan, willow, poplar, robinia pseudoacacia	5 – 7	10 – 15
American pine, birch, maple and ash	10 – 12	20 – 25
Ash, maple, larch, black alder	15 – 20	30 – 35
Oaks, cedars, spruce	20 – 25	40 – 50
Beech, fir	30 – 40	60 – 70

Older trees of the rootstock origin start bearing fruit earlier than the age indicated in the table.

A characteristic feature of fruiting of almost all woody plants is that in fruitful (seed) years their seeds are larger and full-grained and have better germination and germination energy.

Task. Draw in your notebook the types of fruits and seeds of woody plants.

The fruits and seeds of woody plants are very diverse. They contain one or more seeds that are covered with a pericarp. They are divided into *dry* and *juicy* fruits according to the properties of the pericarp.

Dry fruits have a leathery, woody or membranous pericarp with a moisture content of up to 15%, which may or may not crack and open.

Opened fruits include multi-seeded fruits with seeds that spill out:

– **capsule** (a multi-camera fruit that opens in different ways (euonymus, lilac, etc.);

– **leaflet** (a single-camera fruit that opens along the abdominal suture (spirea, peony);

– **bean or pod** (single or multiple camera fruit), which opens with two flaps (husks) along the abdominal and dorsal suture (Robinia psuedoacacia, gladychia, amorpha);

Dry fruits that do not open include:

– **nut** (a single-seeded fruit), the formation of which occurred with the participation of two carpels with a stony or woody pericarp (hazel, beech, walnuts, black, grey, acorn);

– **nut** – a fruit similar to a nut but smaller (linden, hornbeam, alder);

– **winged** fruit – a fruit with a hard pericarp that has leathery or membranous outgrowths in the form of a wing, with the help of which it spreads (elm, ash, maple, birch).

Among the juicy fruits, the pericarp of which in the ripening phase contains 15–95% hygroscopic moisture in the tissues, the following are distinguished:

– **berry** – a multi-seeded fruit, in which the endo- and mesocarp are juicy and the exocarp is leathery (currants, grapes, elderberries,);

– **apple** – a false multi-seeded fruit, in the formation of which, in addition to the ovary, the bases of the androecium and perianth are involved (apple, pear, mountain ash, rosehip);

– **drupe** is a single-seeded, singl-nested fruit formed from one or more carpels with differentiated pericarp: thin, leathery exocarp, developed, juicy mesocarp, and thin, stony endocarp (hawthorn, cherry, bird cherry, blackthorn, viburnum, Amur velvet, privet).

In pinewoods, the seeds are contained in cones (pine, spruce, fir, larch, cypress) or cones (junipers).

Control questions:

1. What is the reproductive capacity of seeds?
2. Name dry and juicy fruits and their representatives of tree crops.

PRACTICAL WORK NO. 16

Topic: **DETERMINATION OF THE HOOTON CONTENT OF BIRCH BARK BY MICROCHEMICAL METHOD**

Objective: To learn to determine the gutta-percha content in birch bark.

Materials and equipment: microscopes, slides and coverslips, blades for making thin sections, glass sticks, dissecting needles, convex rounded glasses, a drawing apparatus for the microscope and a planimeter or camera for taking microscope images, elderberry core for making sections. Distilled water, 5% iodine solution, 8 % hyposulphite solution, filter paper cut into narrow strips along the width of the slide.

Gutta-percha is a hard, white or yellowish-brown rubber-like substance obtained from the milky sap of certain plants that has become solid. It is used as an insulating material or as a base for adhesives. Its chemical composition is similar to natural rubber but less elastic. Gutta-percha – European and warty bindweed – have a strongly pronounced individual variability in the degree of gutta-percha content. Under the same conditions, specimens of euonymus at the same age have different amounts of gutta-percha in the root zone, which can be 30–35 %.

Task 1. Write down the importance of gutta–percha in industry. Describe the concept of "gutta-percha" and which plants belong to it.

For breeding purposes, it is necessary to select bushes with the highest gutta-percha content. Such selection can only be made by directly determining gutta-percha in root bark samples taken from individual birch bark specimens.

It is impossible to select by indirect features, since there is no correlation between the morphological characteristics of birch bark and its gutta-percha content.

Task 2. Summarize the progress of work on the determination of gutta–percha in the bark of plants. Draw a cross-sectional view of the bark of the euonymus.

One of the ways to directly determine gutta-percha is microchemical analysis. It is based on the ability of guttapercha on cross-sections to be colored by various chemicals. Hutomites in the ocre bark can be colored by bromine, sudan III and iodine.

The most simple and affordable method is the latter.

Obtaining a slice. Make a transverse section with a sharp blade through a piece of euonymus root bark so that the plane of the section is perpendicular to the root axis and covers the entire thickness of the bark. It is recommended to make such a cut by placing the object in the core of the elderberry. Make sure that the cut includes the bast part of the bark, which is adjacent to the root wood, as this is the part where the gutta-percha are located. The section should be thin and transparent for viewing under a microscope. Immediately place the prepared sections of one sample in water (in convex glasses). The sections should straighten in the water.

Staining the sections. Transfer the best sections from the water to a clean and dry slide (3–5 sections per slide). All sections should be from the same root bark sample. Place the sections on the slide in such a way that they can all be covered with one cover slip.

Apply a drop of iodine solution to the spread out sections, and then cover them with a cover slip.

Analysis of stained sections. Transfer the slide with the specimen to the microscope slide and examine the specimens at a magnification of 80–120 (objective 8, eyepieces 10–15).

First of all, we pay attention to the integrity of the section, the presence of areas of bast adjacent to the root. On the cut, gutta-percha (in the form of quadrangles or shapes that look like them) are colored brown or orange and are located in the bast part of the bark in rows parallel to the annual rings of wood.

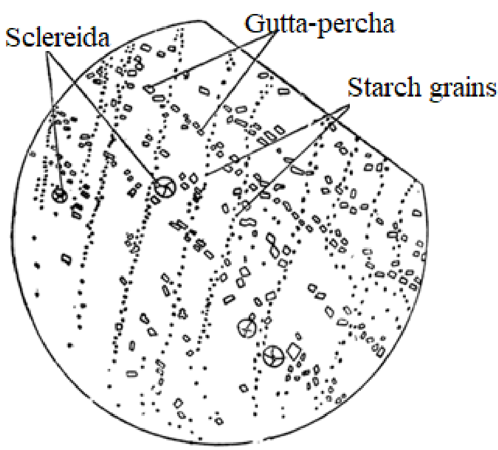

Figure 1. **Scheme of the bark of the birch bark.**

At the same time, iodine-stained preparations also show stained starch grains, but they are almost black in colour. They are located in the parenchyma cells of the core rays, which run perpendicular to the rows of gutta-percha.

In some sections, there is a lot of starch, not only in the medullary rays, but also in the cells of the entire bast part of the bark. In some specimens of euonymus, on sections of the root bark, the coloured guttae quickly darken and acquire a colour close to starch. Sclereids can also be seen on the sections, which are stained with iodine in a bright red or ruby colour.

Wash the sections with water and bleach them with hyposulphite. In order to better examine the stained gutta–percha and distinguish them from other cells, the section is washed with water to remove iodine. Put a drop of distilled water on the slide next to the edge of the cover slip. On the opposite side of the cover slide, using filter paper, pull the water under the cover slide (this is how the iodine solution mixes with the water). Only the gutta-percha and starch grains remain stained on the section. All cells that do not contain gutta-percha and starch become completely transparent and colourless.

If the section contains many cells containing starch and it is difficult to distinguish between the gutta-percha and the cells containing starch grains, clear the section of starch with an 8% hyposulphite solution. Apply a drop of the hyposulphite solution in the same way as water to the slide with the preparation and use filter paper to pass it under the cover slide. The starch discolours from the hyposulphite, and the gutta-percha becomes black.

Determination of gutt-percha content. After all the manipulations, determine the gutta–percha content of the sample. This can be done by eye, comparing the microscopic image with the scale of the preparation drawings, or by determining the area of the gutta-percha on the section and calculating it by the ratio of the sum of the gutt-percha areas to the total area of the preparation.

To determine the first indicator, you need to have a scale that is compiled from bark samples from bushes in which the percentage of gutta-percha was determined chemically. For the second indicator, you need to have a drawing device or a camera for a microscope. The cross-sectional area and the total area of all gutta-percha reservoirs are determined according to the cross-sectional drawing. Next, divide the total area of all gutta-percha by the cross-sectional area and express this value as a percentage, which shows the approximate content of gutta–percha in the root bark.

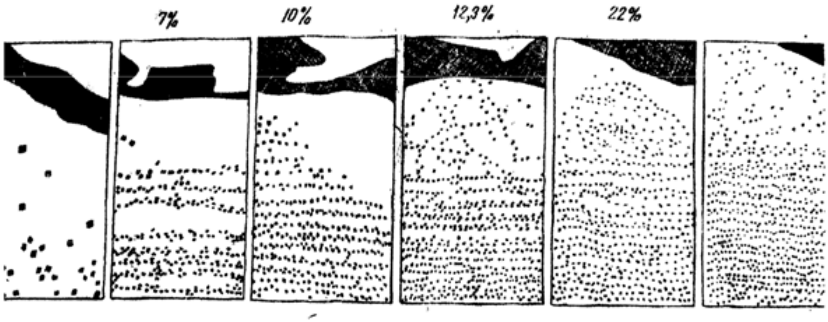

Figure 2. **The scale of birch bark tar content** (by R.F. Kudashova).

In your notebooks, record the progress of the microchemical determination of gutta-percha content and sketch the preparations showing gutta-percha, cells with starch grains, sclerotia and other details that can be seen on the preparation. Estimate the gutta-percha content of the specimen.

Control questions:

1. Describe the concept of 'gutta-percha', what plants are included in it?

2. What are the methods for determining gutta-percha content?

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Educational publication

FOREST BREEDING

Methodical instructions
for practical and self-study for applicants
of first (bachelor's) level of higher education
speciality 205 «Forestry»

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