CULTIVATION OF BARE-ROOTED PLANTING STOCK

TREATMENT OF SOIL IN FOREST NURSERIES

SOIL DISINFECTION

- **Importance**
  - **protects against diseases, pests, weed**
  - **has a stimulating effect on growth**
  - **transforms nutrients into easier to access**

DISINFECTION MAY DAMAGE MYCORHIZATION

a) thermal disinfection

- burning of brushwood (straw etc.) directly on the beds
- flamethrower is not enough
- 14 days before sowing
- layer 30–50 cm, at the depth of 5 cm temperature 90 °C
- disinfection only to the depth of 8–15 cm
- the ashes need to be plough in the soil

b) chemical disinfection

- pouring the soil through a solution of disinfectants
- these are the so-called fumigants - herbicidal, insecticidal, fungicidal, nematicidal effects
- pre-sowing, pre-emergent, post-emergent

c) biological disinfection

- cultivation of plants whose exudates destroy harmful organisms (especially fungi)
- lupines; clover; rape (against nematodes),
- they are grown 2 years before sowing
- biopreparations – IBEFUNGIN, POLYVERSUM, SUPRESIVIT
- watering mixture from herbs (nettle, comfrey, onion, garlic, dandelion)

d) steaming

- steam machine
- steam temperature 105°C
- to the depth of 10 cm


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PI JE 332


Egedal
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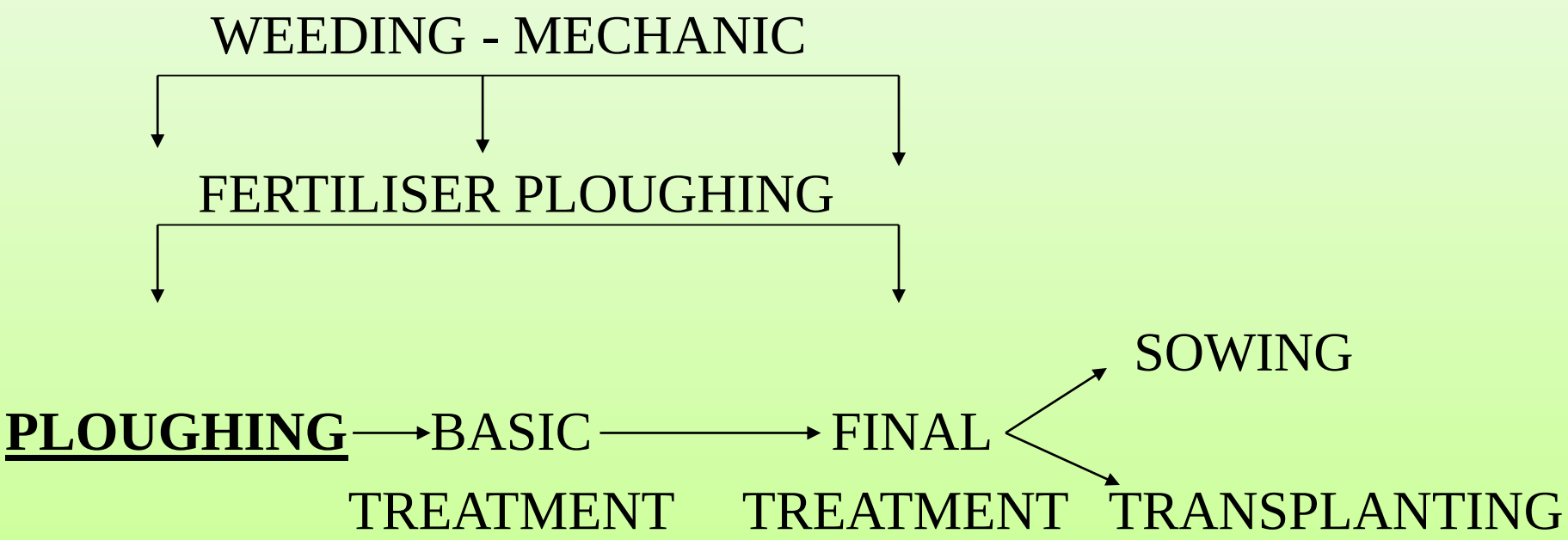
4 months after steaming

SOIL PREPARATION IN FOREST NURSERIES

PREPARATION OF SOIL - SCHEME



AUTUMN PLOUGHING

- **is significantly more useful than the spring one (both biologically and technologically)**
- **depth up to 35 cm (for all types of soil and tree species – seedlings, transplants)**
  - **shallow depth - development of weak and deformed roof system**
- **always necessary in heavier soil (aeration, water penetration)**
- **date - after lifting of seedlings and transplants – immediately**

  - after green fertilization and fallowing – until mid September
- **over the winter in a rough furrow**
  - **heavy soils: harrowing → better frost penetration**
  - **light soils in the valleys: dragging → better water management**

SPRING PLOUGHING

- **extensive method – lifting the plants in the spring**
- **depth - medium and heavier soil: 18-22 cm**
  - light soil: up to 30 cm
- **date - just before final treatment of the soil to be cultivated**
  - heavier soil: at optimal humidity
- **immediately after ploughing: dragging – to prevent the soil drying and clodding**
- **unwanted soil compacting → tool aggregation**

- <u>Both in the autumn and in the spring: fertilization, adjustment of physical characteristics of the soil</u>

- <u>Ploughing substituted by spading</u>

Effect of depth of topsoil on size of roof system (%)

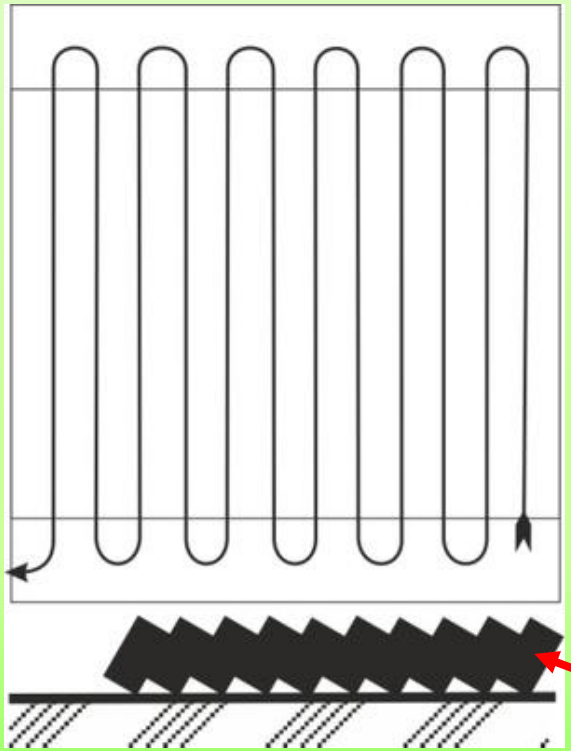
	Depth of topsoil (cm)			
	22	26	30	35
Beech 2+0	100	112	142	176
Spruce 3+0	100	106	117	124

Effect of depth of ploughing on growth of beech 2+0

	Height	Size of root system
Always deep ploughing	100	100
Ploughing 2 times, to 22 cm	71	73
Ploughing 4 times, to 22 cm	68	55

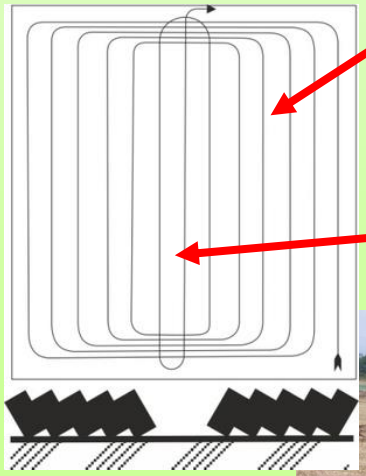
PLOUGHING TECHNIQUE

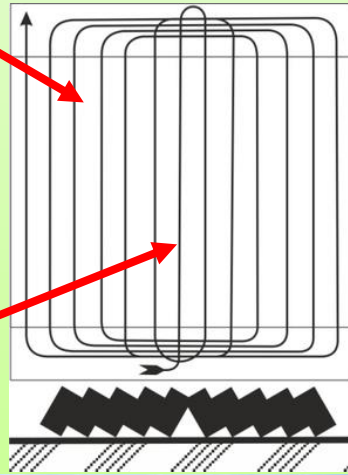
- **ploughing techniques**
  - **<u>single-side ploughing -</u> “flat” (turning plough) is the best option**



PLOUGHING TECHNIQUE

- **ploughing techniques**
  - **<u>single-side ploughing -</u> “flat” (turning plough) is the best option**
  - **it is not recommended to apply <u>“folding” or “breaking”</u>**



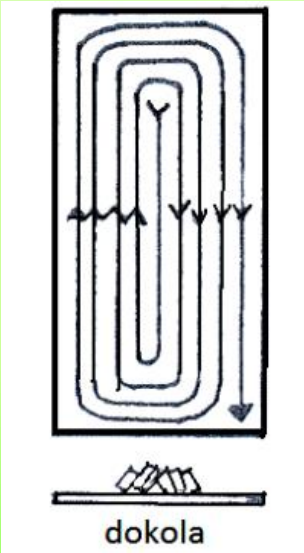


crater

bump

PLOUGHING TECHNIQUE

- **ploughing techniques**
  - **<u>single-side ploughing</u> - "flat" (turning plough) is the best option**
  - **it is not recommended to apply "<u>folding</u>" or "<u>breaking</u>"**
  - **ploughing "<u>around</u>" is not permitted**



PLOUGHING TECHNIQUE

- **on the plane: alternate single-side ploughing**
- **on the slope: “throw” the furrow to the slope**
- **tractor optimal speed 4-6.5 $km.h^{-1}$**
- **ploughing dry and wet soil is not permitted**

CORRECT PLOUGHING CRITERIA

- **the top layer is put onto the bottom of the furrow**
- **the ploughing is equally deep throughout the area**
- **the furrow is properly tilted (uniform wrinkling over the whole surface, the same colour)**
- **autumn ploughing: high furrow**
- **the under-topsoil layer must not be carried onto the surface**
- **the slice is split (no clods or banks)**
- **the furrow bottom must be rough**

SPRING TREATMENT OF SOIL
- AREAS PLOUGHED IN THE AUTUMN

a) **<u>Preparatory work</u>** ("removal of snow and excessive wet")

➢ ***accelerate the snow melting***

- **sprinkle with ashes, sooth, peat (200 kg.hectare^{-1})**
- **no thick layers – insulating properties**
- **non-toxic black dyestuff can be used**

➢ ***accelerate the soil drying*** (in the wet sections of the nursery)

- **aerate to the depth of 10–15 cm**

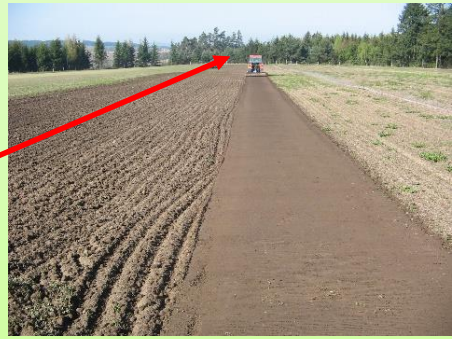
b) Basic treatment ("rough levelling, fertilization")

- *harrowing out rootstock weed*
  - harrowing to align furrows is not recommended – evaporation
- *dragging* - immediately after the furrow tops get dry
  - diagonally to the furrows, in two perpendicular directions
  - prevents drying out and allows the weed germinating

- *fertilization* (up to 15 cm)
  - immediately after dragging
  - preferably before the final soil treatment

c) Final pre-sowing treatment (creating optimal conditions for growing plants)

- ***(fertilization)***
- ***aeration*** **- to the depth of the sowing seeds (approx. 5 cm)**
  - rotavator is recommended (slow speed)
- ***levelling the soil surface*** **– mainly if small seeds are sown**
  - **recommended equipment: soil brushes, land levellers, bed formers**
  - **manual after-levelling welcome**
  - **test by irrigation**



- ***soil flat rolling***
  - **prevents seeds from falling into greater depths**
    - **ensures proper seed contact with soil, prevents the seed rotation**
    - **correct rolling operation - the footprint of an adult is not deeper than 1 cm**
    - **it is not so important if sowing machines that squeeze out sowing stripes or grooves are used**

EFFECT OF SOIL LEVELLING ON SUCCESS OF SOWING SPRUCE 1+0, HEIGHT DIFFERENCE 2 cm PER 1 LINEAR METER (mineral soil, backfilling 0.8 to 1.0 cm)

Sowing locality	Germination rate (%)	Mortality (%)	
Top	84	39	dry season
Middle	91	10	
Dip	76	19	wet season
Check (flat)	100	3	

does not matter - slope, but height differences
- slope → erosion

Effect of soil compacting before sowing on germination rate and root system deformation

	Soil compacting (footprint in cm)	Germination rate (%)	Deformation (%)
beech 1+0	1.0	100	0
	2.0	96	0
	0.5	91	68
spruce 1+0	1.0	100	0
	2,0	52	0
	0.5	77	14

Tool holder

Tool holder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Trailer

Aeration of the under-topsoil layer

- over time, the under-topsoil layer becomes compacted - prevents water and root penetration - must be aerated to the depth of 50-60 cm

Single-side plough

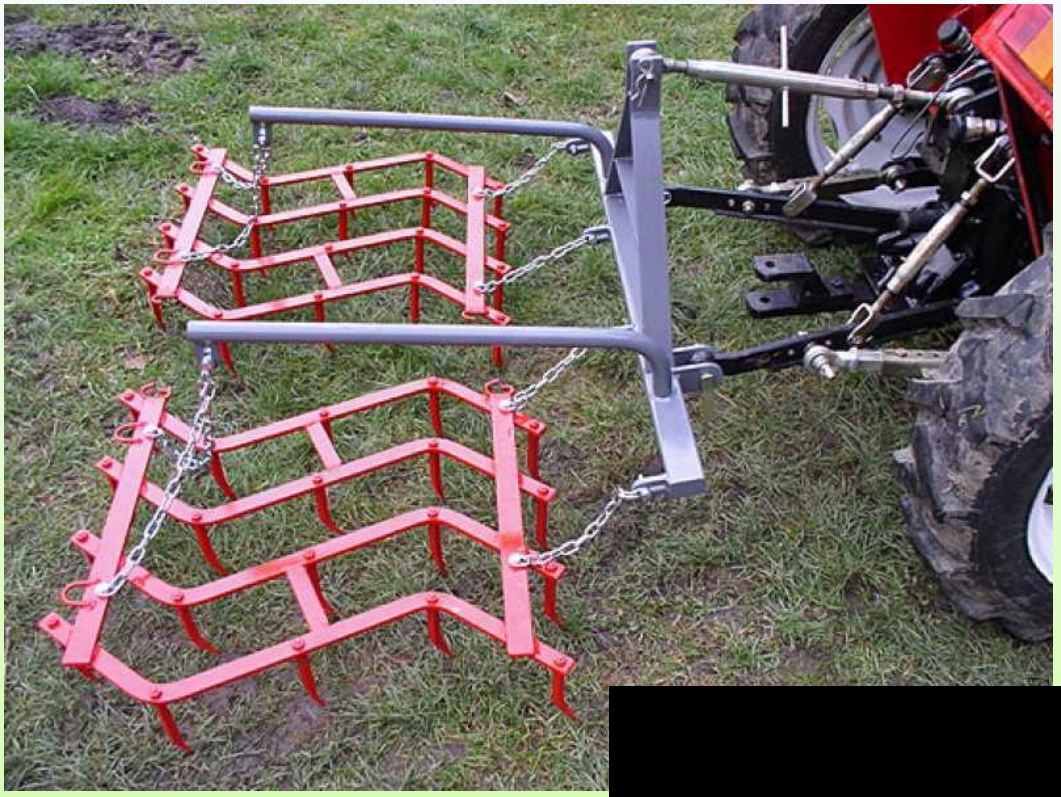
Turning plough

Ploughing

Special ploughing machine (engraving(spading)

Solid fertilizer spreader

Harrows



Soil aerating rotavator

Soil aerating rotavator

Soil aerating tiller

Soil treatment cultivator


Farmet
K 300
extra STEEL line

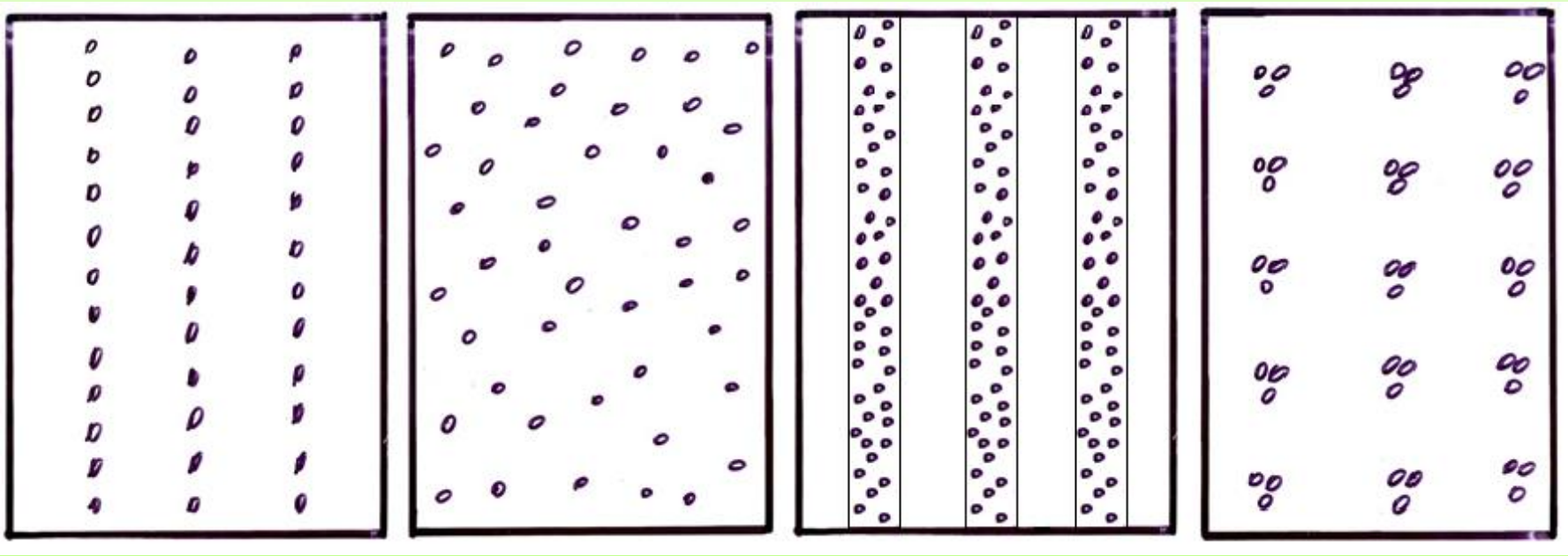
Soil levelling roll

Bed shaping

Bed shaping

SOWING TECHNIQUES

- depending on the size of seeds, height of the plants
  - in rows (grooves) of width 2 cm - big seeds only
  - in stripes of width 5 or 7.5 cm
  - area-wide (better homogeneity, lower costs)
  - pinching is not used in forest nurseries



IN ROWS, ROW SOWING

BROADCAST SOWING, SOWING BY SCATTERING

STRIPE SOWING

NEST, PINCHING SOWING

SOWING - SOIL PROPERTIES

- conifers - light, humic soil, pH 4.5 – 5.5
- broadleaves - also heavy soil, pH 5.5 – 6.5
- Exceptions - birch, oak – pH 4.5 – 5.5
  - beech – pH 5.0 – 6.0

SOWING IS NOT RECOMMENDED ON THE SOIL:

- where seedling falling have occurred
- more than 10 % of humus
- after green fertilisation
- after fertilisation with dung

SOWING DOSE

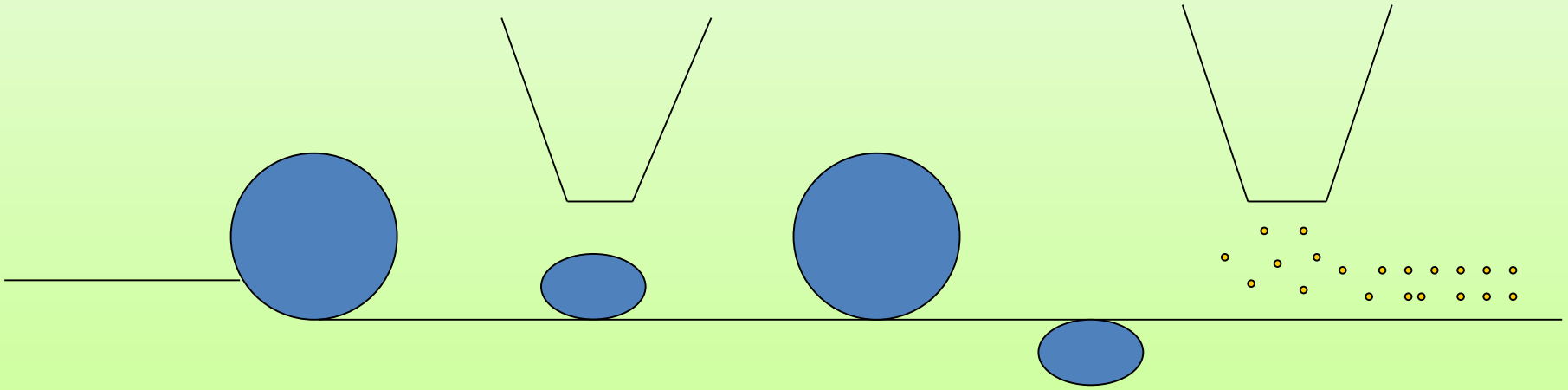
- depends on the conditions in the nursery
- tree species
- seed lot quality
- cultivation method

- oversized sowing = poor quality
- better - calculation

$$N = \frac{10 \cdot A \cdot V}{K \cdot Č} \cdot k$$

N - dose in grams per area unit
A – weight of 1000 seeds
V - required number of plants per area unit in pieces
K - seed germination capacity in %
Č - seed purity v %
k - nursery coefficient (from 1.0 to 6.0)

SOWING SCHEME



levelled soil

compacted soil roll

sowing

roll

pressed seed

backfill

SOWING TECHNIQUE

- sowing machines → all seeds
- manually → big or winged seeds
  → broadcast sowing
  → germinated seeds
  → stratified seeds
  (if the medium cannot be separated)
- treatment of the surface before sowing - sowing within 3 days after treatment
  - weed (chemically, without residua)
  - aeration (crust, up to 2 cm)
  - manual after-levelling, pre-sowing watering

SOWING TIME

EARLY SPRING (March) (soil +5 °C)
- stratified seeds, seeds with higher water content and shorter life time
- *Abies*, *Quercus*, *Acer*, *Carpinus*, *Fagus*
- light soil, necessary anti-frost protection
- plants do not suffer so much from falling and frost

SPRING (soil +10 °C)
- dry and germinated seeds without dormancy
- *Larix*, *Picea*, *Pinus*, *Pseudotsuga*…
- warm soil (otherwise they would decay)

LATE SPRING (second half of May)
- only in higher altitude and the tree species suffering from frost
- all types of tree species
- frequent watering is needed; frequent falling
- it is suitable to sow stimulated seeds

LATE SOWING
- always less growth!
- secondary dormancy

SUMMER a) **maturing seeds with short lifetime**

(May-August) - ***Betula*, *Salix*, *Ulmus***

- **sow immediately after collection**
- **necessary protection against high temperatures**

b) collection "in green state"

- ***Tilia*, *Fraxinus*, *Carpinus***
- **sow immediately after collection**
- **necessary protection against high temperatures**

AUTUMN - **seeds with higher content of water and shorter life**

(from September) time,

- **non-stratified seeds with short dormancy,**
- **stratified seeds – non-germinated**
- ***Abies*, *Pseudostga*, *Fagus*, *Quercus*, *Pinus* and *Larix***
- **only light and not wet soil**
- **damage - rodents, frost**

WINTER - **on the snow *Betula***

- **modification - seeds with short dormancy /beech/**
- **seeds with higher water content /oak/**

BACKFILL

- function - regulation of temperature and humidity fluctuation
  - protection against flooding
  - protection against birds
- characteristics - powdery, aerated
  - does not form crust
  - insulates very well
  - optimal pH, chemically inert - also deformations of above-ground parts

mortality
delayed growth

- most suitable: light colour (reflects sun rays)
- the choice depends on - availability
  - woody species of seeds
  - price

→ sand – coarse-grained, siliceous (2 mm)
→ fine stone pulp – diabas, gabro
→ soil – humic, sandy, clayey sand - only in big seeds
→ peat – fresh, sieved, in mixture with sand
→ saw dust – better deciduous, not fresh, better with sand
→ composted bark – autumn sowing (also winterization)

- at 100 % watering without backfill - risk!
- big seeds: soil can be used (from paths)
- free of weed seeds

HEIGHT OF BACKFILL

4-8 cm	**- *Quercus, Juglans, Aesculus, Corylus***
2-4 cm	**- *Fagus***
1,5-2 cm	**- *Acer, Fraxinus, Tilia***
1-1,5 cm	**- *Abies, Carpinus, Robinia pseudoacacia***
0,5-1 cm	**- *Picea, Pinus, Pinus strobus, Pseudotsuga***
0-0,5 cm	**- *Larix, Sorbus, Ulmus***
without	**- *Populus, Salix, Betula***
	(safer with small backfill - sowing homogeneous mixture of seed and backfill)

general - 2 x longest axis of the seed

COVERING THE SOWINGS

- **purpose - minimisation of abrupt climatic changes**
  - **→ evaporation**
  - **→ extreme temperatures**
  - **→ torrential (sudden) rain**
  - **→ hail**
  - **→ late frost**

- **accelerated germination**
- **uniform emergence of seedlings**
- **minimised damaged caused by birds**
- **reduced weed emergence**

a) <u>Low cover</u> (most frequent)

- sewn stripes or the whole bed is covered
- the cover is put just on the soil (backfill)
- covered stripes - wooden material (wooden plates, half-logs - impregnated)
  - plates made from inert materials
  - PE foil - black for early spring sowing
    - light for other sowing
  - plastic textile
  - impregnated paper

- fixed, removed during germination time or folded in stripes in between

- **covering beds**
  - **tape bamboo and reed mats**
  - **dense plastic mesh, textile**
  - **powdery materials - mainly for autumn sowing (useful during winterization as well)**

    - best - forest leaf litter, peat

- **<u>must be removed during germination</u>**
  - **prevents the germination plants from growing**
  - **development of fungi**
  - **late removal = pulling out germinating plants**

b) Elevated cover

- protects the whole bed, at the height of 10–20 cm above surface
- sides – plates fixed with hooks
- top – mats, mesh…
- suitable
  - tree species sensitive to autumn freezing weather (beech, fir)
  - where damage by birds is likely

BROADCAST SOWING – main principles

- **the same concept as in stripe sowing**

SUBSTRATES

- **in frames, vegetation beds (plates, prefabricated units)**
- **necessary to harden, height – the entire root system in the substrate**
- **same principles as in full sowing into mineral soil**

Sowing mechanism of sowing machine

Sowing machine Rath

achine

Sowing

Machine aggregation – minimising travel and soil compacting

Backfilling device

Backfill

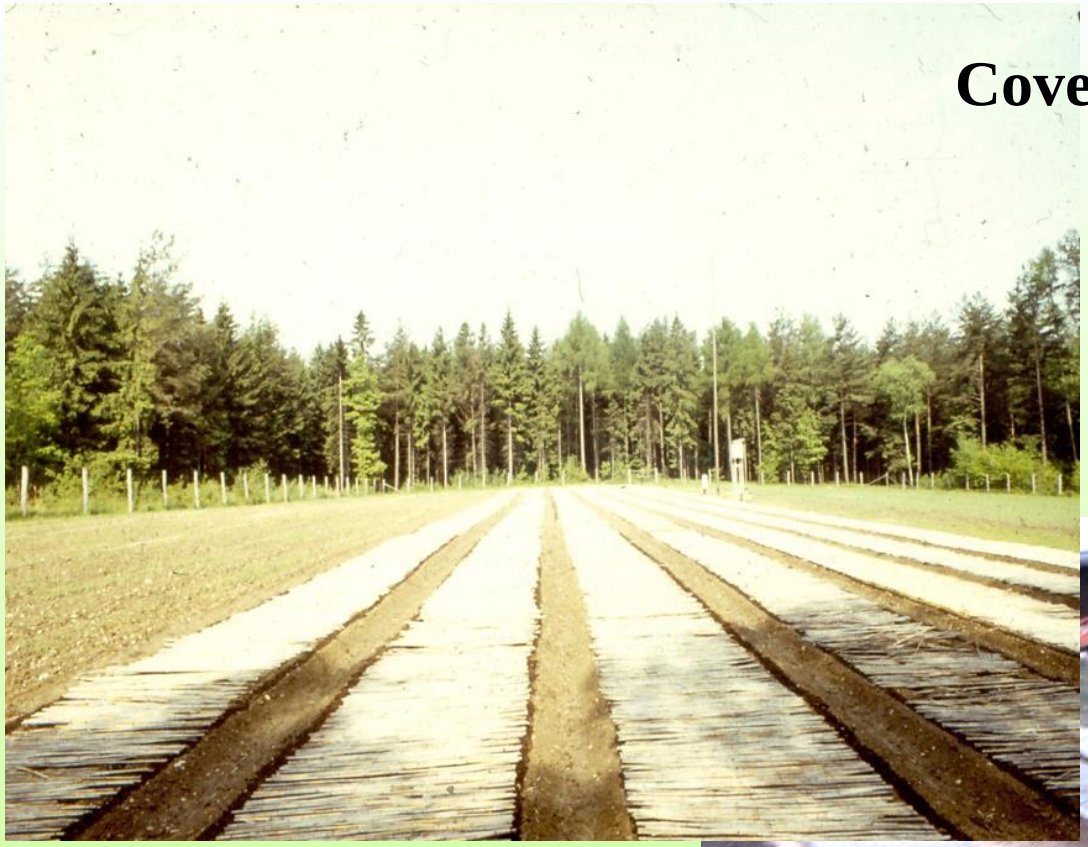
uneven

Uneven backfill of beechnuts with peat

Backfill with fresh sawdust - toxic

Backfill with big wood fractions – not recommended – the bacteria needed for decomposition consume nitrogen (N) – it is necessary to use more fertilizer

Covering the sowings with mats



Covering the sowings with textile

fixing with soil

fixing with plastic pins

fixing with wooden poles


Structure for elevated cover

Broadcast sowing, elm

Broadcast sowing, beech

Broadcast sowing, beech

Broadcast sowing, pine

Uneven broadcast sowing, spruce

Over-dense sowing, spruce

Stripe sowing – 5-row technology

Stripe sowing, spruce – 5-row technology

Stripe sowing, pine

Uneven stripe sowing 7 row technology

Stripe sowing
(too wide stripes do not allow treatment of the plants in the middle of the stripes)

Row sowing
7-row technology

Row sowing

Row sowing

Row sowing
4-row technology

Uneven row sowing

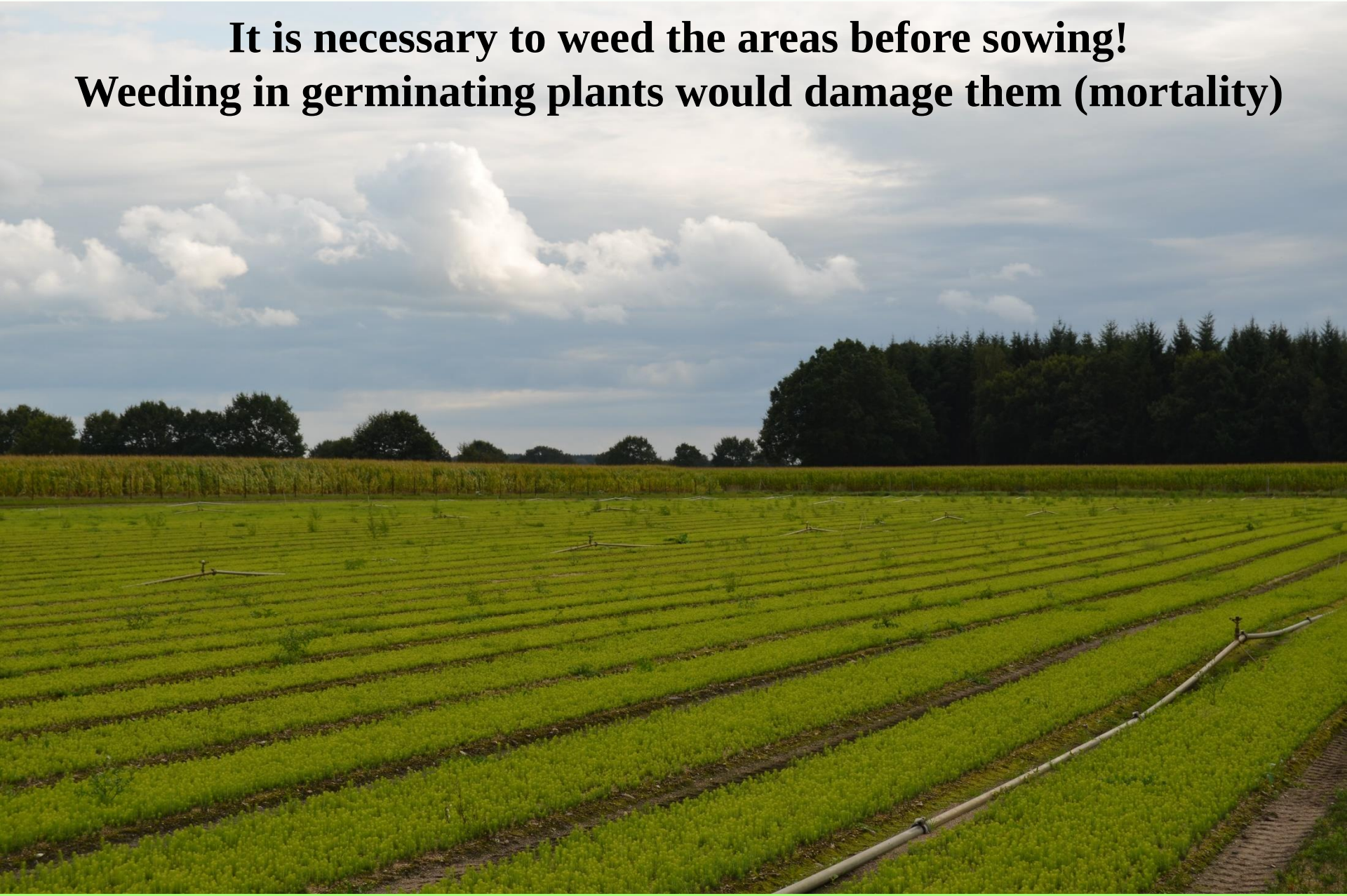
Germinated sowing, beech

Sowing beech – the backfill with clayish soil has formed a crust difficult to penetrate for the germinating seedlings

“Path effect” – lack of nutrients in the middle of beds (yellowish seedlings)

Uneven beds – problem with the care of the plants

It is necessary to weed the areas before sowing!
Weeding in germinating plants would damage them (mortality)



It is necessary to weed the areas before sowing!

CULTIVATION OF PLANTING STOCK BY TRANSPLATING

TRANSPLATING

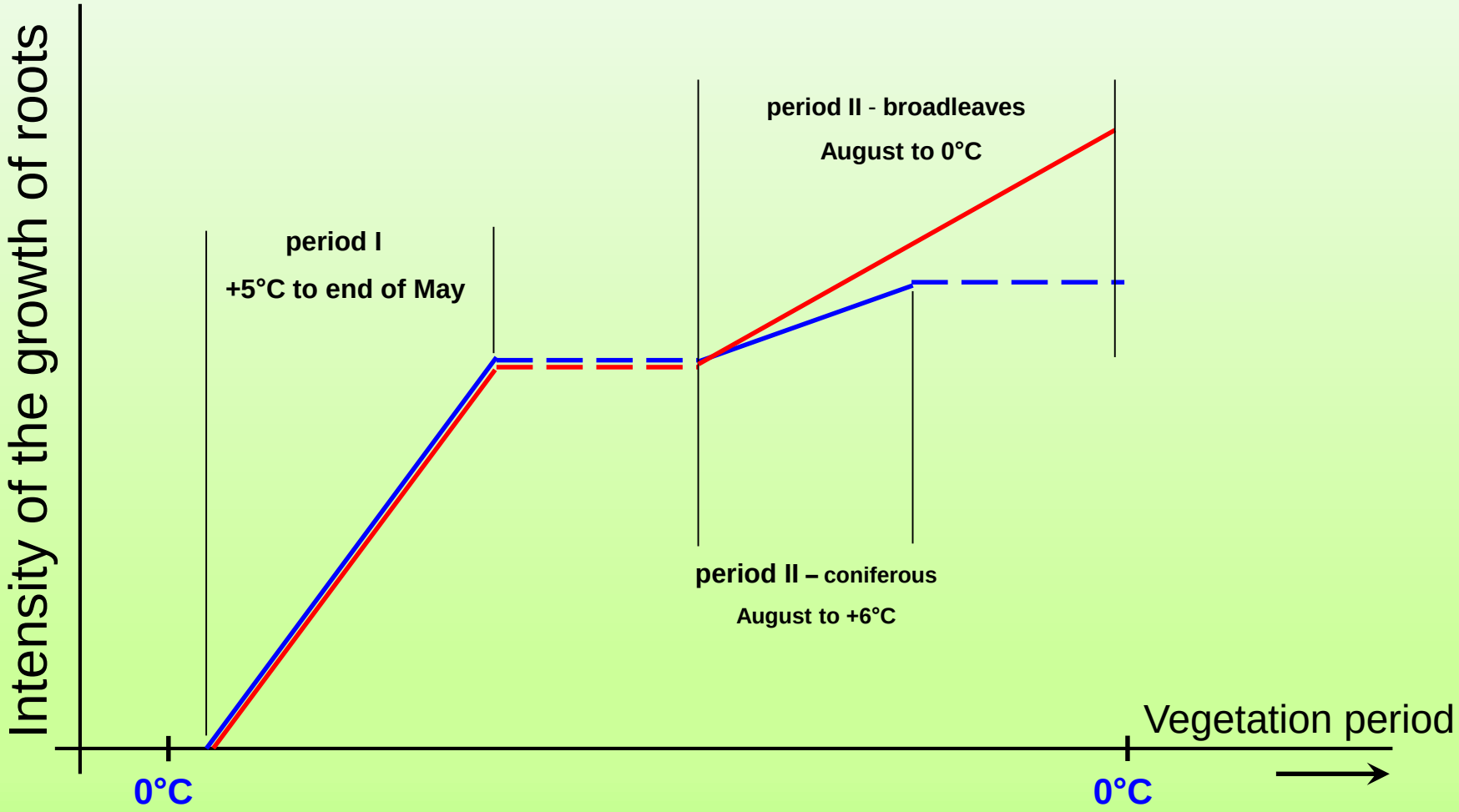
Definition:

“moving (seating) the plants (seedlings, transplants, semi-saplings) to mineral soil after cutting their root system in regular spacing”

- **even container plants may be transplanted**

- **target**
  - **rich root system**
  - **developed above-ground part**

GROWTH PERIODS OF ROOT SYSTEM



TRANSPLATING TIME

SPRING

- **March–April, localities at higher altitude in June**
- **seedlings must be in dormancy (not in bud) !**
- **transplanting - depends on the condition of the soil (+5 °C)**
- **firstly, larch is transplanted (and large-sized plants)**
- **secondly, broadleaves are transplanted – *Quercus* first, *Alnus* and *Betula* last**
- **next, coniferous are transplanted, *Pinus sylvestris* is more sensitive than *Picea abies* and *Abies alba***
- **finally (partially in bud) *Pseudotsuga menziesii* a *Abies grandis* may be transplanted**
- **followed by a post-transplanting shock (small increment)**

SUMMER

- from mid August to 10th of September
- the given year´s seedlings may be transplanted as well
- protection and perfect irrigation are necessary

AUTUMN

- latest time: mid November (the plants need to root before winter)
- only in lower altitudes, on light soil without risk of freezing

BIOLOGICAL PRINCIPLE - PERIODICITY OF GROWTH OF ROOT SYSTEM!

SUMMER AND AUTUMN TRANSPLANTING DOES NOT DECREASE THE INCREMENT!

TRANSPLANTING TECHNIQUES

MANUALLY

- **transplanting pins**
- **transplanting frames**
- **transplanting laths**
- **into slot**

SEMI-MECHANIC
(slots are machine-made)

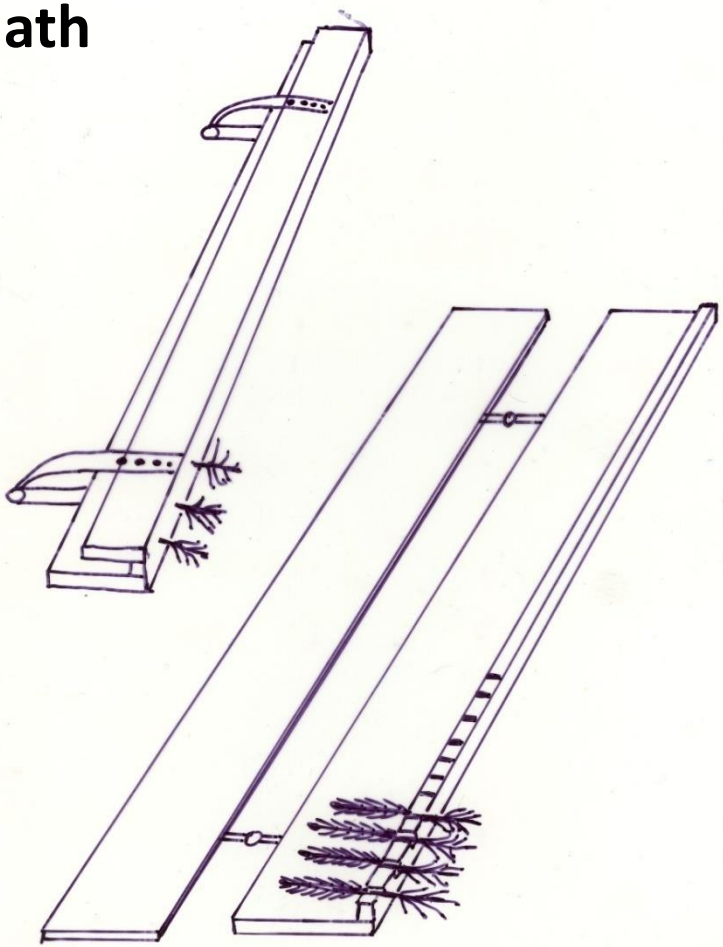
USE OF MACHINERY – TRANSPLANTING MACHINES

- **endless chain with clamps**
- **pressure discs**
- **belt-like magazine (as with a machine gun)**

Transplanting with pins

Transplanting with pins

Transplanting lath



Transplanting frame

Transplanting with the help of the transplanting frame

Trencher (makes slots)


20

RECOMMENDED DISTANCE FOR TRANSPLANTING

- **distance between rows - 20.8 cm**
- **the distance between the plants in a row must not be less than 5 cm; it is differentiated by the height above-ground part**
  - ***Picea abies* 1+2, 2+2 – 7.5 cm to 10 cm**
  - ***Pinus sylvestris* 1+1 – 5 cm to 10 cm**
  - ***Pinus sylvestris* 1+2 – 10 cm to 12 cm**
  - ***Abie alba* 2+2, 2+3, 3+2 – 7.5 cm to 15 cm**
  - ***Larix decidua* 1+1 – 7.5 cm to 10 cm**
  - ***Larix decidua* 1+2 – 12.5 cm**
  - **deciduous (except for *Populus*) 1+1, 1+2 – 10.0 cm**
  - **deciduous (except for *Populus*) 1+3, 2+2 – 15.0 cm**

RECOMMENDED DISTANCE FOR TRANSPLANTING

- **<u>in general</u> transplants - 21 x 10 cm**

  large-sized plants

  broadleaves - 35 x 35 cm

  conifers - 50 x 50 cm

RULES OF CORRECT TRANSPLANTING

- use biometrically and physiologically quality material
- protect plants from drying!!!
- transplant
  - to properly treated soil (no later than 3 days after final soil treatment)
  - at least 5% of humus in the soil
  - in favourable weather conditions (windless, cloudy, evening or morning hours)
- after transplanting: treatment – complete, fix, (loose = aerate), irrigate
- maintain the same distances for the whole time of transplanting

- **transplant to slots and furrows deep enough**
  - **place the roots in their natural position**
  - **avoid primary deformation**
- **put into soil up to the root collar (2 cm above), vertically**
- **perfect contact of the roots with the soil**
- **the soil must be wet, otherwise it would take water from the roots**
- **straight rows of transplants**
- **transplanting time: 2 years**
  - **in year 1: the plants “sit” – the above-ground part does not develop much (shock)**

ADJUSTMENT OF THE ROOT SYSTEM TO BE TRANSPLANTED

- prerequisites
  - let new roots developing
  - avoid deformation of the root system
- broadleaves without tap root and conifers to length of 10-12 cm
- strong tap roots 1+0 to 15 cm
- strong tap roots 2+0 to 18 cm
- smooth cut – just before the transplanting
  - with a knife
  - scissors with round edges
- short-cut even mechanically damaged roots
- direct the cut perpendicularly to the root axis

Effect of humus content in soil on quality of root system in planting stock

(same nursery, treated with peat, i.e. 31 %, pH KCl 5.2, topsoil 32 cm)

Tree species	Humus content (%)	Portion of plants (%) with standard root system
Fagus sylvatica 2+0	1	17
Fagus sylvatica 2+0	3	53
Fagus sylvatica 2+0	6	93
Picea abies 2+2	1	47
Picea abies 2+2	3	75
Picea abies 2+2	6	98

Effect of size of seedling roof system on success of transplanting

Volume of root system / Volume above-ground	Portion of standard transplants (%)	
	Picea abies	*Fagus sylvatica*
1:1	98	96
2:1	99	98
1:2	44	26

Effect of sorting seedlings of *Picea abies* 2+0 on homogeneity of transplants 2+2

Seedling height	Height of transplants
10 – 14 cm	34 – 45 cm
7 – 17 cm	26 – 66 cm

Transplanting fragments of *Picea abies* 2+0 (standard plants - in %)

Plants	Years after transplanting		
	1.	2.	3.
Fragment	0	18	47
Check	0	91	-

Transplanting machine

with pressure discs

Transplanting machines with another plant handling system

Transplanting machine Egedal

Detail of the plant handling system in the transplanting machine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Transplanted spruce

Transplanted spruce


Transplanted spruce – wrong angle of transplants

Transplanted linden

Transplanted oak

Transplanted fir

CULTIVATION OF PLANTING STOCK BY ROOF SYSTEM UNDERCUTTING

CULTIVATION OF PLANTING STOCK BY UNDERCUTTING (comparison with transplanting)

POSITIVES

- does not cause deformation of the root system, faster development of the root system
- the increment is not decreased much ⇒ shorter production time
- fully mechanized, less labour

NEGATIVES

- does not use the production area so well (bigger distances)
- issue of knife blades

Needs suitable soil in the nursery (topsoil 35 cm, skeleton free, humus 5 %, approx. 28 % of physical clay)

UNDERCUTTING – SCOPE OF APPLICATION (it is possible to undercut any tree species)

1. Standard cultivation of planting stock (transplants)

1. GROUP

- tap root is formed at early stage
- *Quercus, Fagus sylvatica, Juglans nigra*
- it is possible to undercut in year 1, when the first spring increment is finished (0.5-0.5 or 0.5-1.5), at the beginning of the second vegetation period (1-1) as the latest

2. GROUP (often transplanted)

- **tree species that can be undercut in year 2**
- **conifers – *Pinus sylvestris, Pseudotsuga menziesii*...**
- **broadleaves – *Tilia, Carpinus*...**
- **undercutting at the beginning of the vegetation period, in the year of collection (1-1)**
- **exceptions – *Pinus sylvestris* in year 2, during the vegetation period, when the increment is finished (1.5-0.5); *Picea abies, Abies alba* in year 3 (3-2)**

3. GROUP

- **tree species that are not normally transplanted, but - as yearlings, they are too small to be planted and as two year old, if not cutted, they are overgrown and their root system is small**
- ***Fraxinus, Ulmus, Alnus, Betula, Acer, Larix, Populus***
- **they can be undercut at the beginning of the second vegetation period (1-1)**
  - **the quality of their root system gets better**
  - **the increment of year 2 is decreased**

2. Cultivation of large-sized plants or saplings

- after two years from transplanting/undercutting:
  - the roots are becoming thinner
  - the roots grow to bigger distance

⇓

  - the positive effect of transplanting/undercutting is lost
  - difficulties and damage of root systems during lifting
- by undercutting after two years from the preceding treatment it is possible:
  - to recover concentrated root system
  - to substitute the second transplanting
- undercutting must be completed:
  - at the beginning of vegetation period
  - in the year of lifting or after two years

Effect of undercutting on main morphological parameters of beech

(undercut at the beginning of vegetation period in year 2 - humus 5%)

	Total height (cm)	Diameter of root collar (mm)	Length of root system (cm)
2+0	68	7.8	32
1-1	52	10.3	25
	(%)		
2+0	100	100	100
1-1	76	132	78

Effect of undercutting on parameters of beech roof system

(undercut at the beginning of vegetation period in year 2 - humus 5 %)

	Volume above-ground part (ml/plant^{-1})	Volume of root system (ml/plant^{-1})	Volume of fine roots (ml/plant^{-1})
2+0	21	19	4 – 5
1-1	17	41	22
	(%)		
2+0	100	100	100
1-1	81	215	550

When undercutting,

- **it is necessary to keep to the prescribed depth**
  - **the depth must be as prescribed – fundamental prerequisite**
  - **the depth is specified in tables but it is possible to deduce it from biological aspects (see below)**

- **the soil is elevated ⇒ it needs to be pressed**
  - **preferably in aggregation with undercutting (mechanically)**
  - **often substituted by plentiful watering**

- **irrigation**
  - **it is not necessary when undercutting before the vegetation period; if not provided, mechanical pressing is required**
  - **absolutely necessary**
    - **when undercutting during vegetation period**
    - **when undercutting to shallow depth**
  - **undercut under conditions of optimal soil humidity**

- **frequency of plants**
  - **max. 35 plants per 1 linear stripe**
  - **max. 25 plants per 1 linear row**
  - **broadcast sowing max. 200 pcs.m^{-2}**
  - **by increasing density, improper reduction and root intertwinning the increment is decelerating**
  - **optimal number, according to the height above-ground, is significantly lower (distance as in transplanting)**
- **maximum thickness of roots at undercutting point (depth of undercut deduced)**
  - **decision should be based on average plants!**
  - **6 mm, but there are exceptions *Tilia* - 3 mm, large-sized plants - 10 mm (otherwise the wounds will be difficult to heal, mainly in broadleaves)**
  - **3 cm of the root needs to be cut away as the minimum**
  - **do not cut away more than 1/3 of the volume of the root system**
  - **length after undercutting + new increment = length of root system according to ČSN 48 2115**

- **undercutting vertical or horizontal roots**
  - **in tree species with distinctive tap root**
    - **– horizontal cut**
  - **in *Picea abies* (both seedlings and transplants)**
    - **– vertical cut**
  - **in *Pinus sylvestris***
    - **– vertical and horizontal cut**
  - **in other trees (normal size seedlings) – horizontal cut, but vertical cut is good too ⇒ better lifting**
  - **large-sized plants, saplings or over-grown items**
    - **– horizontal and vertical cut**

Whole-bed undercutter

Whole-bed undercutter

Horizontal undercutting of oak seedlings

Row undercutters

Vertical undercutter


Fagus 2+0
Fagus 1-1


Quercus 2+0
Quercus 1-1