

PROGRESS

Promoting Green Deal Readiness in
the Eastern Partnership Countries

ADAPTIVE APPLE CULTIVATION: BEST PRACTICES

NULES for Ukraine



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ADAPTIVE APPLE CULTIVATION: BEST TECHNOLOGICAL PRACTICES

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Cultivated apple tree (*Malus domestica*)

Family: *Rosaceae* (Rose family)

Genus: *Malus* (Apple)

Origin: Sievers' wild apple (*Malus sieversii*)
from the mountainous regions of Central Asia

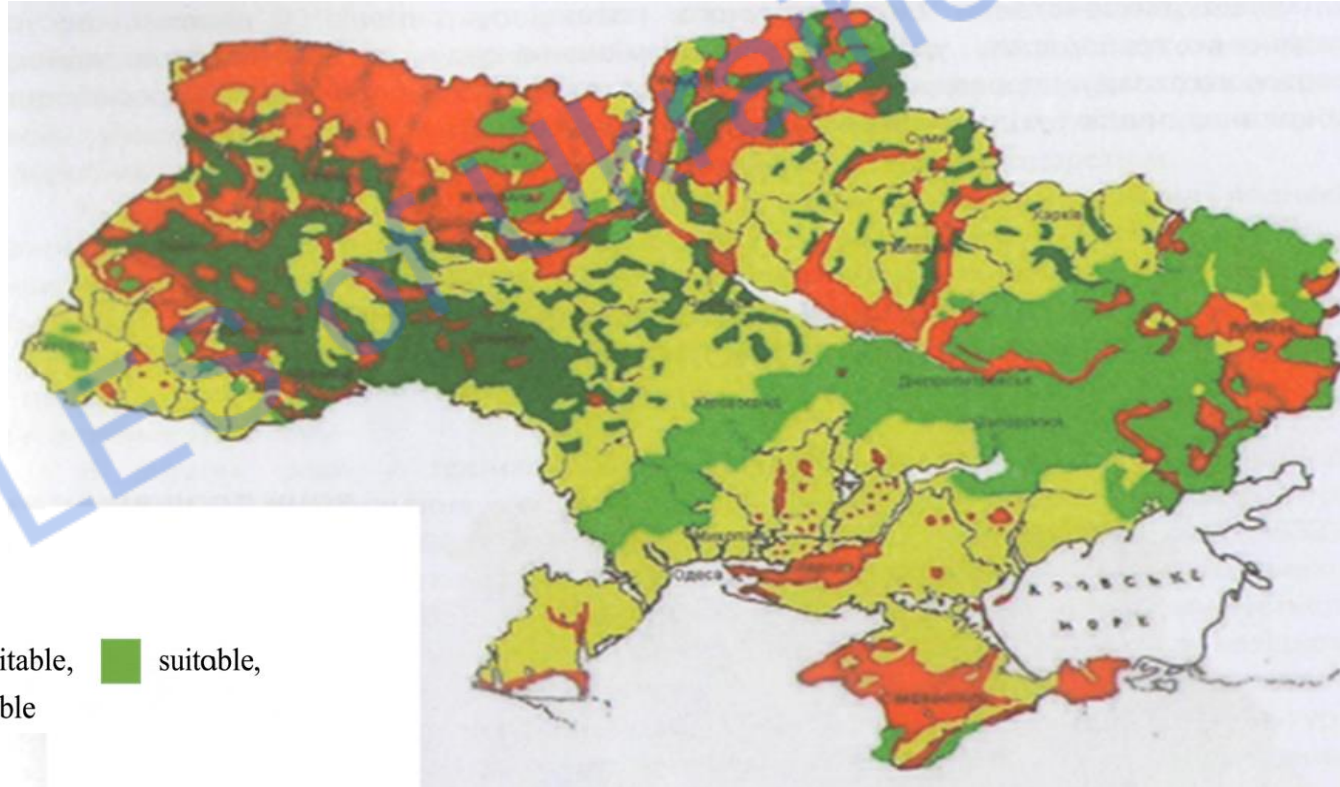


Significance of apple cultivation:

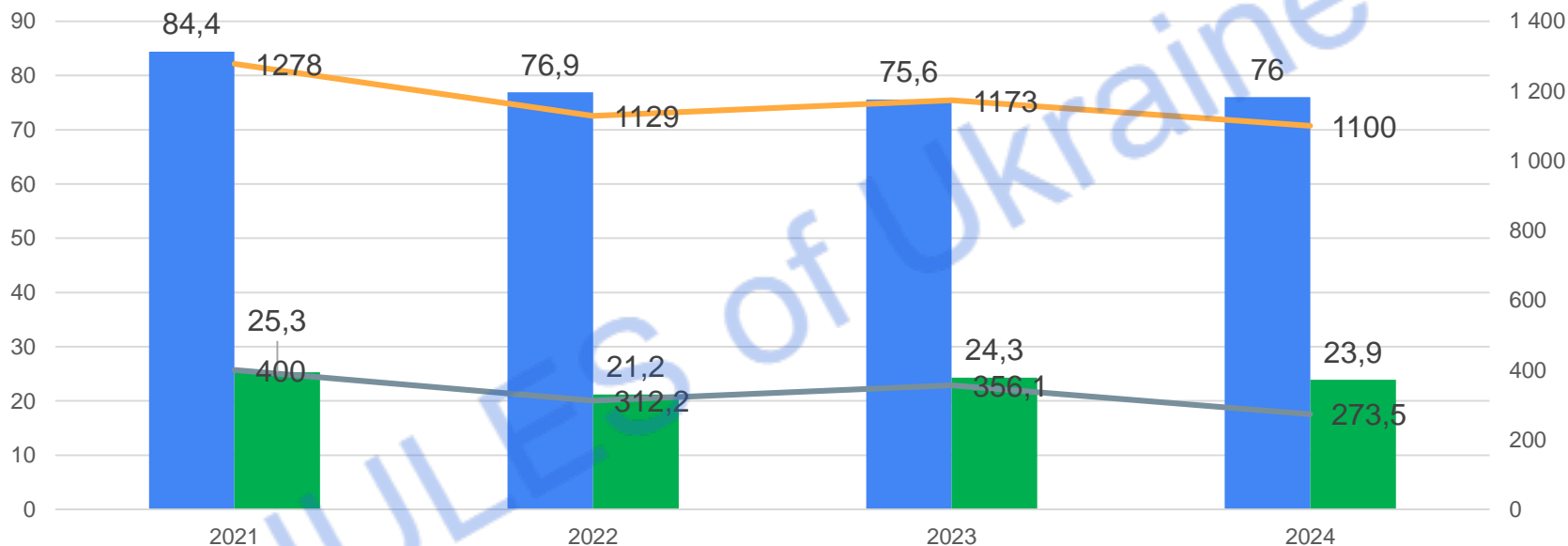
- thanks to their good keeping quality, apple fruits have a prolonged period of consumption when fresh, up to 12 months
- apples contain easily digestible carbohydrates, organic acids, pectins and bioactive compounds
- is a good source of raw material for the processing industry, particularly for the production of concentrates, juices, dried fruit, jams, marmalades and so on.
- Apple orchards are an excellent source of nectar and pollen for bees during flowering
- Apple varieties with red-coloured leaves and fruit have an ornamental effect



THE SUITABILITY OF UKRAINE'S REGIONS FOR APPLE CULTIVATION



AREA OF APPLE ORCHARDS AND GROSS APPLE HARVEST IN UKRAINE



- Total area, thousand hectares
- Area under cultivation by enterprises, thousand hectares
- Gross yield at enterprises, thousand tonnes



Global apple production – 81.7 million tonnes, orchard area – 4.8 million hectares



CLIMATIC CHALLENGES IN APPLE CULTIVATION

Sharp temperature fluctuations (day-night) in winter

SUNBURN OF THE BARK AND CAMBIA OF FRUIT TREES

An increase in the average daily air temperature during the growing season

SHORTER FRUIT MATURATION PERIOD, SHORTER HARVEST WINDOW

Excessive solar radiation in summer

SUNBURN OF LEAVES, FRUIT, SLOWING OF THE SYNTHESIS OF PLASTIC SUBSTANCES, UNMARKETABLE, UNSUITABLE FOR STORAGE HARVEST, FRUIT AFFECTED BY GLASSINESS





CLIMATIC CHALLENGES IN APPLE CULTIVATION

Excessive rainfall during the second half of the apple tree's growing season

Fruit cracking, phytopathogen infection, deterioration in flavour

Prolonged drought in summer

SLOWING OF METABOLIC PROCESSES, IMPAIRED DIFFERENTIATION OF GENERATIVE BUDs, FRUIT DROPPING, DETERIORATION IN FRUIT QUALITY, FUNCTIONAL DISORDERS

Heavy rainfall in the first half of the growing season

INTENSIVE SHOOT GROWTH, POOR DIFFERENTIATION OF FRUITING STRUCTURES

Insufficient moisture supply in winter

FREEZING OF THE ROOT SYSTEM, VEGETATIVE ORGANS AND REPRODUCTIVE STRUCTURES, YIELD BELOW TARGET



CLIMATIC CHALLENGES IN APPLE CULTIVATION



Windstorms

- FRUIT DROPPING REDUCED YIELD

Hail, squalls

- DAMAGE TO FRUIT, LEAVES AND FRUIT – POOR-QUALITY, NON-STANDARD HARVEST

Frosts following prolonged thaws

- INDUCED SAP FLOW – FROST DAMAGE TO FRUIT SETS, VEGETATIVE BUDs, WOOD

Spring frosts

- Damage to flowers and ovaries – low yield, substandard fruit



THE IMPACT OF CLIMATE CHANGE ON SOILS:

DEGRADATION OF ORGANIC MATTER

Rising air temperatures stimulate the activity of soil microorganisms, leading to the rapid decomposition of humus and excessive CO₂ emissions into the atmosphere

WATER EROSION

Changes in precipitation patterns, frequent downpours

WIND EROSION

Prolonged droughts combined with strong winds in areas of the orchard where there are no cover crops

SECONDARY SOIL SALINISATION

A consequence of intense moisture evaporation, which is not balanced by the amount of rainfall



REQUIREMENTS FOR APPLE VARIETIES IN THE CONTEXT OF GLOBAL CLIMATE CHANGE:

- heat and drought tolerance
- resilience to temperature fluctuations during periods of relative dormancy
- high concentration of cell sap (sugars, amino acids)
- good elasticity of cell membranes
- late flowering period (10–12 days later than usual)
- long flowering period, up to 14 days
- pollen capable of germinating even after a brief drop in temperature to -2..-4 °C



APPLE VARIETIES, LEADERS IN GLOBAL PRODUCTION

GALA and its clones



Clone	Advantages	Disadvantages
Must	high tolerance to heat	Susceptible to sunburn, not disease-resistant; the skin near the stem cracks during significant fluctuations in humidity
Royal	Winter-hardy	moderate resistance to sunscald, does not tolerate air or soil drought, not immune, short dormancy period, susceptible to bacterial blight, damaged by mites
Shniga	high adaptability to climate change, does not require a temperature difference for anthocyanin synthesis	prone to sunburn in winter, moderately cold-hardy
Brookfield	tolerates February thaws well	requires protection from sunburn; during periods of significant moisture fluctuations, the skin near the stem cracks
Devil	synthesises colour pigments excellently, even at high night-time temperatures	requires shade, prone to fruit shattering



RED DELICIOUS and its clones

Clone	Advantages	Non-loud
Red Cap	heat-tolerant, resistant to: sunburn; powdery mildew; fruit drop	flowers in the early to mid-season; flowers die at $t -2.0\text{ }^{\circ}\text{C}$; susceptible to scab
Jeromin	heat- and winter-hardy, with high flowering intensity; highly resistant to scab and powdery mildew; resistant to sunburn	prone to irregular fruiting
Scarlet Spur	flowers profusely; suitable for dense plantings; fruits are transportable	poor winter hardiness, critical temperature during flowering $-2.0\text{ }^{\circ}\text{C}$; susceptible to spider mites
Early Red One	resistant to sun damage and heat; suitable for dense planting	poor winter hardiness; not resistant to spring frosts; susceptible to scab; not resistant to bacterial blight



FUJI AND ITS CLONES

Clone	Advantages	Disadvantages
Fuji Kiku 8	Capable of synthesising sugars and anthocyanins under low light conditions, moderately winter-hardy, low resistance to thaws	requires a long growing season; not resistant to sunburn; poor drought tolerance; vulnerable to return frosts
Beni Shogun	has a shorter fruit ripening period compared to the original; resistant to sunburn, moderately winter-hardy	poor drought tolerance
Aztec	synthesises anthocyanins better than the original; moderately winter-hardy	prone to sunburn, requires regular watering, has a long growing season, and tends to revert to its original colour
Zhen Aztec	high resistance to fruit cracking, winter-hardy, tolerates February thaws well	prone to sunburn, but has excellent regenerative capacity



Monitoring the condition of tree stands using drones and satellites

- Determining the extent of infestation or damage to plantations (or individual trees) based on chlorophyll levels
- Conducting an orchard inventory (losses, yield assessment)

Soil analysis and targeted fertilisation

- Electromagnetic scanning (determining the mechanical and nutritional composition of the soil)
- Precision fertiliser application (only in those areas of the orchard where it is necessary)

Precision irrigation and fertigation

- Use of precise soil moisture sensors
- Irrigation automation: activating water supply when moisture levels drop to a critical point, with the addition of fertilisers

Disease and pest control

- Use of digital traps for precise pest population monitoring
- Use of smart sprayers, saving up to 30% on pesticides

Automated harvesting: the use of robotic equipment fitted with soft vacuum grippers that suck up the fruit

ASPECTS OF ESTABLISHING AND MAINTAINING APPLE ORCHARDS IN THE CONTEXT OF CLIMATE CHANGE

Choosing a site for an apple orchard

A flat area with a slight slope (up to 2–3°), a site sheltered from prevailing winds, with soil suitable for growing apple trees



Avoid south-facing slopes, as there is a risk of significant damage to the bark of young trees from sunscald and to flowers from spring frosts due to the trees' earlier development in spring

It is not recommended to establish an apple orchard in depressions and valleys where cold air stagnation is possible

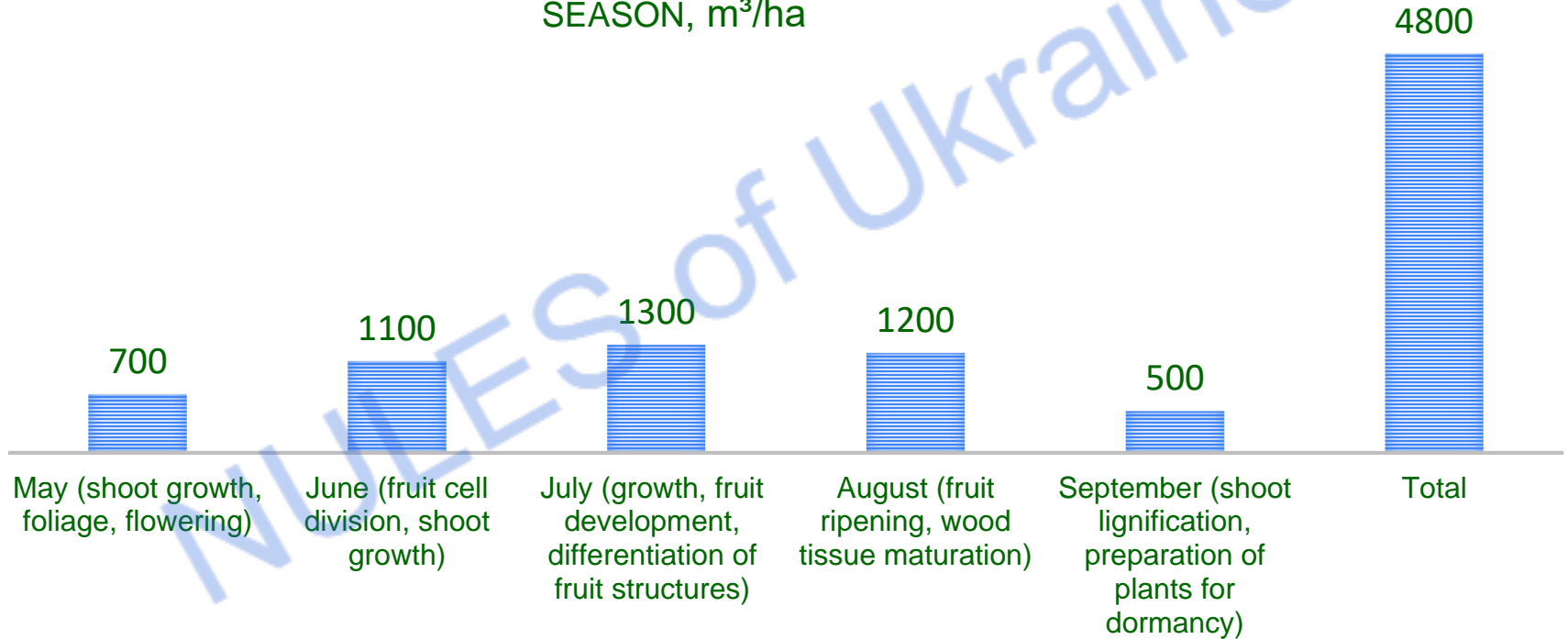
Landscaping of the apple orchard

The layout of the garden area involves:

- defining the boundaries of blocks and plots within a block;
- the farmyard;
- the road network;
- installation of trellises;
- **installation of an irrigation network*;**
- **installation of hail protection nets*;**
- **installation of solar panels*;**
- **creation of garden protection and windbreak lines***
- erecting a fence around the orchard



WATER REQUIREMENTS OF AN INTENSIVE APPLE ORCHARD DURING THE GROWING SEASON, m³/ha



Drip irrigation

- Benefits:

- providing the plant with the necessary amount of water
- minimising water loss
- moistening only the root zone
- automation of watering
- increased crop yield and quality
- conservation of natural resources
- the ability to apply fertilisers with irrigation water
- prevention of a number of fungal diseases

Disadvantages:

*clogging of the irrigation system (nozzles)
salt accumulation*



The cost of a drip irrigation system for an average farm is 50,000–200,000 UAH, depending on the scale of the project. Payback period: 2–5 years

Sustainable water sources for irrigation

1. Rainwater

- is only possible if there are large areas of roofing (fruit storage, fruit processing complex, farmyard, etc.)

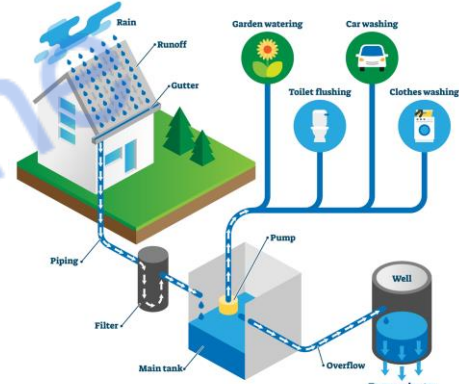
2. Water from open water bodies

- disadvantages: turbidity exceeding 50 mg/l, presence of phytopathogenic microflora (requires settling, treatment)

3. Water from artesian wells

- drawback: contains high levels of calcium, iron and chlorine; requires settling; optimal EC for apple trees is 1.0–1.5 mS/cm

RAINWATER HARVESTING



-Roof collection system: the cost of installing tanks and filtration systems ranges from €3 to €25 per m³, depending on the materials used;
-infiltration troughs or wells: one-off equipment costs — €500–2,000 for a 0.5-hectare plot

Garden preparation (land preparation for a garden)

1 year Sowing of green manure crops (white mustard, oil radish, marigolds)

Deep loosening of the soil (the root system penetrates the soil to a depth of up to one metre), improving drainage and aeration

Prevention of plant pathogens

Nitrogen fixation, phosphorus mobilisation

Weed control



2–3 years Planting garden strawberries

Strawberry roots release organic acids, sugars and amino acids into the soil, which promote the growth of beneficial soil bacteria

The fibrous root system of strawberries creates a dense network of channels for microorganisms

Additional income



4 years Sowing green manure, a mixture of vetch and oats

Replenishment of soil mineral composition: vetch – nitrogen, oats – potassium and structure

Year 5

PLANTING AN APPLE ORCHARD

Ornamental hedges, windbreaks*

Functions of orchard shelterbelts:

- protecting apple orchards from dry winds in spring and summer and cold winds in winter
- protecting the soil from wind erosion

Requirements for orchard shelterbelts:

- multi-tiered (2–3)
- absence of diseases and pests common to apple orchards
- durability

Main tree species for creating orchard shelterbelts:

- small-leaved lime
- small-leaved lime
- Norway maple
- black elder
- yellow acacia

For creating windbreaks – pyramid poplar



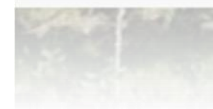
*On average, creating 1
hectare of a windbreak strip
can cost between 50,000
and 100,000 UAH.*

Planting trees in the garden*

- Planting method: rows; planting pattern: 2.5–3.5 × 0.5–1.0 m; planting density: 8,000–2,900 trees/ha
- Rows should run from north to south
- Mandatory requirement for row spacing – 0.5–1.0 m wider than the dimensions of the farm's existing machinery
- Optimal area for an intensive orchard: 8–12 ha; under conditions of global climate change: 6–8 ha, dimensions 200×300 m, 200×400 m

Why is it necessary to optimise the block size?

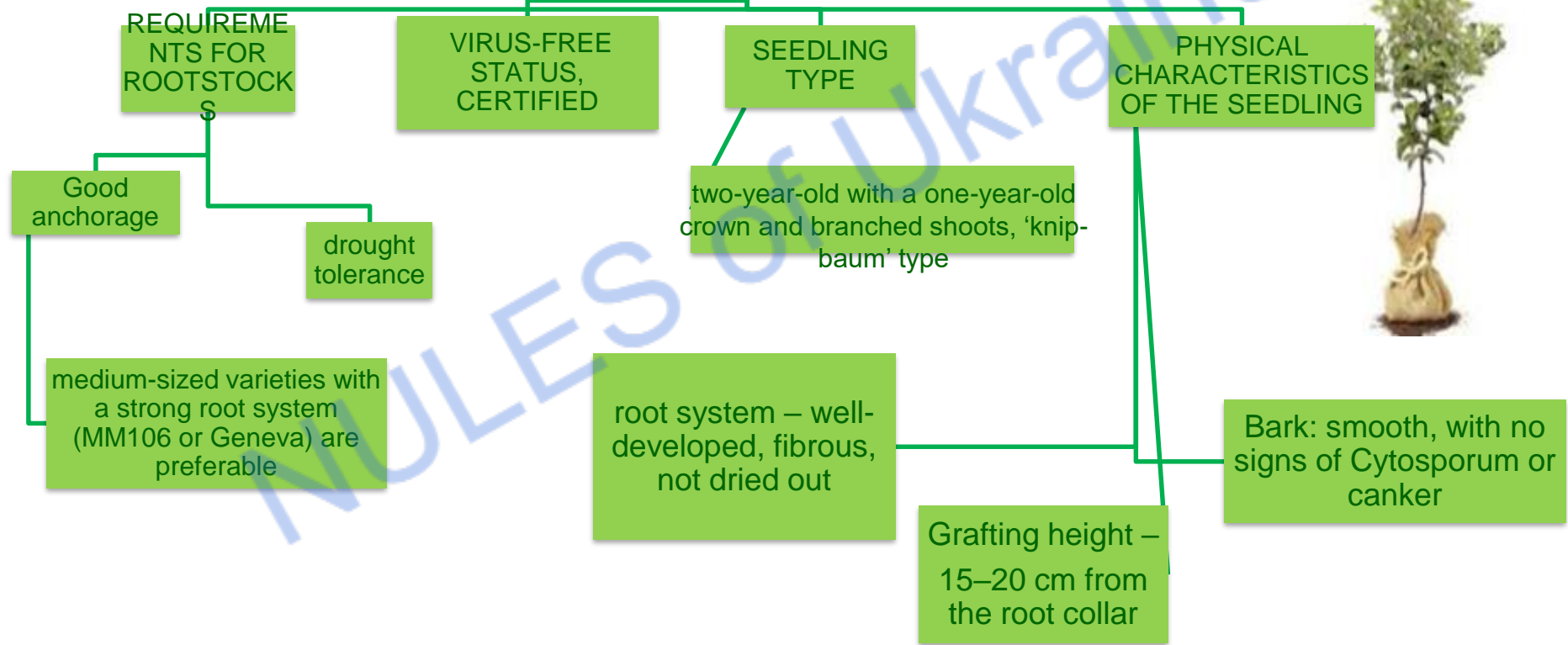
- Protection from the wind, creation of more windbreaks
- Greater efficiency of drip irrigation – it is easier to maintain a consistent water pressure in the irrigation tape
 - Ability to plant crops on a single soil type and adjust irrigation rates
 - Easier installation of trellises, hail protection structures and solar panels (shorter structures, greater resistance to storms)
- Improved logistics – application of protective treatments, subsoiling, and harvesting



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REQUIREMENTS FOR PLANTING MATERIAL



Planting an apple orchard

1. Subsoiling – loosening depth 40–60 cm
2. Application of organic matter (compost or humus), minimum rate – 40–60 tonnes/ha, with localised application (5–6 kg/m²), biochar, which acts as a ‘battery’ for fertilisers and moisture, remaining undecomposed in the soil for hundreds of years
3. Preparation of planting pits:
 - size 60x60 cm
 - adding hydrogels to the root zone to help retain moisture
 - inoculation with mycorrhizae, which helps the plant absorb water and nutrients
4. Mandatory mulching of the tree trunks (mulch layer 12–15 cm)*



Mulching* and its benefits

- temperature regulation - a 10–15 °C reduction in soil temperature
- moisture conservation – evaporation reduced by 60–80%
- protection against water erosion
- soil nutrition – improves soil structure and enriches it with organic matter
- stimulates beneficial biota
- reduced weed growth
- reduces the risk of fruit cracking
- protects the root system of trees from frost damage



Mulching materials and their uses

Straw/hay – effectively reflects UV rays, reduces weed growth, decomposes quickly, enriches the soil with nutrients

Disadvantages: attracts rodents; as it decomposes, it leaches nitrogen from the soil



Grass clippings – decompose quickly, an excellent source of nitrogen (must be wilted, weed-free)



Wood chips (deciduous species) – long-lasting, promotes the development of beneficial mycorrhiza



Compost – highest nutrient content, improves soil structure



Hail protection nets

Advantages:

- reduced wind load
- protection against hail, birds and pests
- preservation of soil moisture
- improved microclimate in the garden during hot weather

Disadvantages:

- high likelihood of an irregular harvest of varieties whose fruits have a red skin (solution: white or photosensitive netting)
- in high humidity, phytopathogens may develop (additional treatment with fungicides)
- potential pollination issues



The cost of anti-hail netting depends on the size and type of material. For example, Tenax Defender netting is supplied in rolls ranging from 2x100 to 8x100 m. Cost: 3x10 m is approximately 1,467.57 UAH.

Agrovoltatics is a form of sustainable land use that allows for the simultaneous practice of agriculture and electricity generation through the installation of photovoltaic panels or other renewable energy systems without compromising the land's primary function as agricultural land (*Agrovoltatics Association of Ukraine*)

Benefits:

- reduced energy costs
- more environmentally friendly apple production through the use of electric tractors
- protection of the orchard from spring frosts, hail and birds
- reduction in sunburn on fruit
- preservation of soil moisture by reducing water evaporation
- optimisation of photosynthesis
- additional income from the sale of energy

Disadvantages:

- slowing down of pigment synthesis, which reduces the quality of apples
- increased air humidity promotes the development of plant pathogens, additional fungicide treatment



For an average farm, the cost of the system can range from €50,000 to €500,000 depending on capacity. The payback period for an agrivoltaic project depends on the scale and type of farm, but can be up to 10 years depending on electricity prices.

is a combined method of soil conservation in the aisles of an apple orchard, whereby during the first half of the growing season the soil is kept under black fallow (to accumulate moisture in spring), and during the second half – under **green manure crops**



ADVANTAGES

Green manure cover reduces soil temperature by 10–15 °C when heated to 50 °C

The roots of green manure crops create micro-capillaries through which rainwater penetrates deeper, rather than running off the surface

Mown and shredded biomass creates a protective layer that prevents moisture evaporation

Green manure crops return organic matter to the soil (30–40 t/ha)

STEAM-IRON SOIL RETENTION SYSTEM

1. The seeds are broadcast sown before rain, followed by rolling
2. During the budding stage, green manure crops are chopped up and left between the rows as mulch which gradually decomposes
3. The best green manure crops: a combination of cereals (rye, oats) to create a carbon layer, and legumes (white clover, sainfoin) for nitrogen fixation
Only a narrow strip of the orchard's row spacing is treated, where the green manure crops will be sown, at a distance of 0.5 m from the tree trunk when planting on dwarf rootstocks (M.9 rootstock).

For best results, particularly in terms of soil structure, it is advisable to use 5–7-component mixtures containing different root types



A turf-humus soil retention system in the garden* (intensive grass cover) -

REQUIREMENTS FOR CEREALS

Shallow root system

Rapid growth of green
matter

RECOMMENDED MIX RATIOS AND APPLICATION RATES PER HA

Meadow fescue (30%), meadow bentgrass (30%),
pasture ryegrass (20%), white clover (20%)

Sowing rate: bluegrass and meadow fescue 10 kg/ha
each; ryegrass and white clover 6.5 kg/ha each;
total 33 kg/ha

Grasses are sown in the rows of the orchard, with a 0.5
m spacing from trees on dwarf rootstock



Maintenance of the turf-humus system: regular mowing 5–6 times per season, with the clippings left in the garden's aisles (durability: up to 10 years)

Why you should use a turf-and-humus soil management system:

Improving the root system's stress tolerance

During the summer, the temperature under the turf is 10–15 °C lower than on unprotected soil

Reduced moisture evaporation

Physical evaporation from the soil surface is 20–40% lower compared to bare soil

Accumulation of organic matter

Mown grass is mineralised, returning nutrients to the soil

Aggregate stability

Grass roots create a natural 'framework' that prevents the soil from clumping together or turning to dust

Phytosanitary and environmental aspects

Ladybirds, lacewings and other predatory insects live in the grass, naturally keeping a check on aphid and mite populations



PROTECTING YOUR ORCHARD FROM SPRING RETURN FROST*

Measures to prevent damage from spring frosts

Spring
whitewashing of
tree trunks

Delays flowering by 5–7 days, protects the tree from the spring sun, which helps to delay the start of the growing season whilst reducing the risk of sunburn to the trunk

Use of
cryoprotectants

Contact (film-forming agents) – Vapor Guard, Thermo Plus
Systemic (amino acids, hormones) – Megafol, Epin-Extra, Atonik Plus
Microbial-based biostimulants – Kropid

Choice of variety

Plant with varieties that flower late



Critical
temperature
for flowering – 3
°C
for fruit set – 2 °C

GREEN AMMONIA

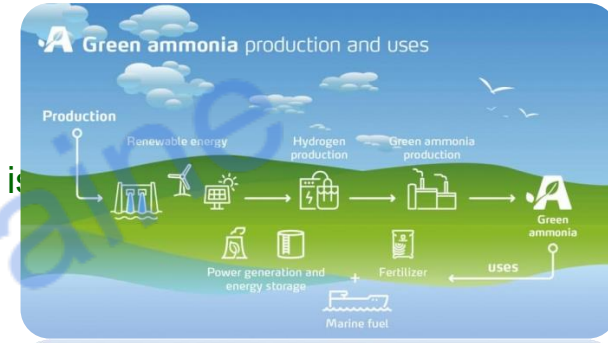
The difference between 'green ammonia' and conventional ammonia, which is produced from natural gas lies in their synthesis. 'Green ammonia' is produced from renewable energy sources (sun, wind). Chemically speaking, its composition, it is identical to NH_3 produced by the Haber-Bosch process, but has a zero carbon footprint.

Developers: researchers from the School of Chemistry at Monash University (Australia)

The authors are exploring the possibility of autonomous production

Use in apple orchards:

- foliar feeding (pink bud stage or after flowering)
 - use as a fungicide and insecticide, at a rate of 3–5 l/ha
- simultaneously suppresses aphid populations and delays the spread of scab, particularly in the early stages



In 2022, the average price of green ammonia from hydrogen in Europe was €952 per tonne. Production of 1 tonne of ammonia using the Haber-Bosch process in Ukraine: \$700

A FERTILISATION SYSTEM FOR APPLE TREES IN THE CONTEXT OF GLOBAL CLIMATE CHANGE

Key challenges

Due to drought, nutrients in the soil become inaccessible to the roots, a situation exacerbated by water stress

Early thaws and sudden frosts require the tree's immunity to be strengthened

Frequent and heavy downpours, especially in the early growing season, rapidly leach nitrogen

Features of the fertilisation system under current conditions

Fertigation: the application of fertilisers together with irrigation water, which allows nutrients to be delivered to the root zone even when the topsoil is dry

Foliar feeding: rapid support during critical stages (flowering, fruit set). Particular attention is paid to **boron, calcium and zinc**

Calcium (Ca) optimisation: in hot conditions, transpiration is disrupted, leading to a calcium deficiency in the fruit (resulting in subcutaneous spotting). Treatments should be carried out regularly, every two weeks, starting from the second wave of fruit drop.

KEY NUTRIENTS FOR AN APPLE ORCHARD

Water-soluble compound fertilisers (Fertigation)

The use of drip irrigation allows the plant to receive the NPK complex as its primary nutrition, even in the most intense heat

Anti-stress fertilisers (Amino acids)

Essential for apple trees during periods of extreme heat or after hail

Amino acids (plant-based)

For rapid entry into the vegetative, flowering and fruiting stages, and fruit differentiation



KEY NUTRIENTS FOR AN APPLE ORCHARD

Micronutrients in chelated form (with an organic coating)

In hot weather or when soil acidity changes, micronutrients (iron, zinc, boron, manganese) become unavailable; chelated fertilisers help

Biostimulants based on seaweed

Seaweed extracts containing natural growth hormones (cytokinins, auxins) that stimulate root system development

Controlled-release fertilisers

These are granules coated with a special polymer shell that dissolves gradually, as the temperature rises

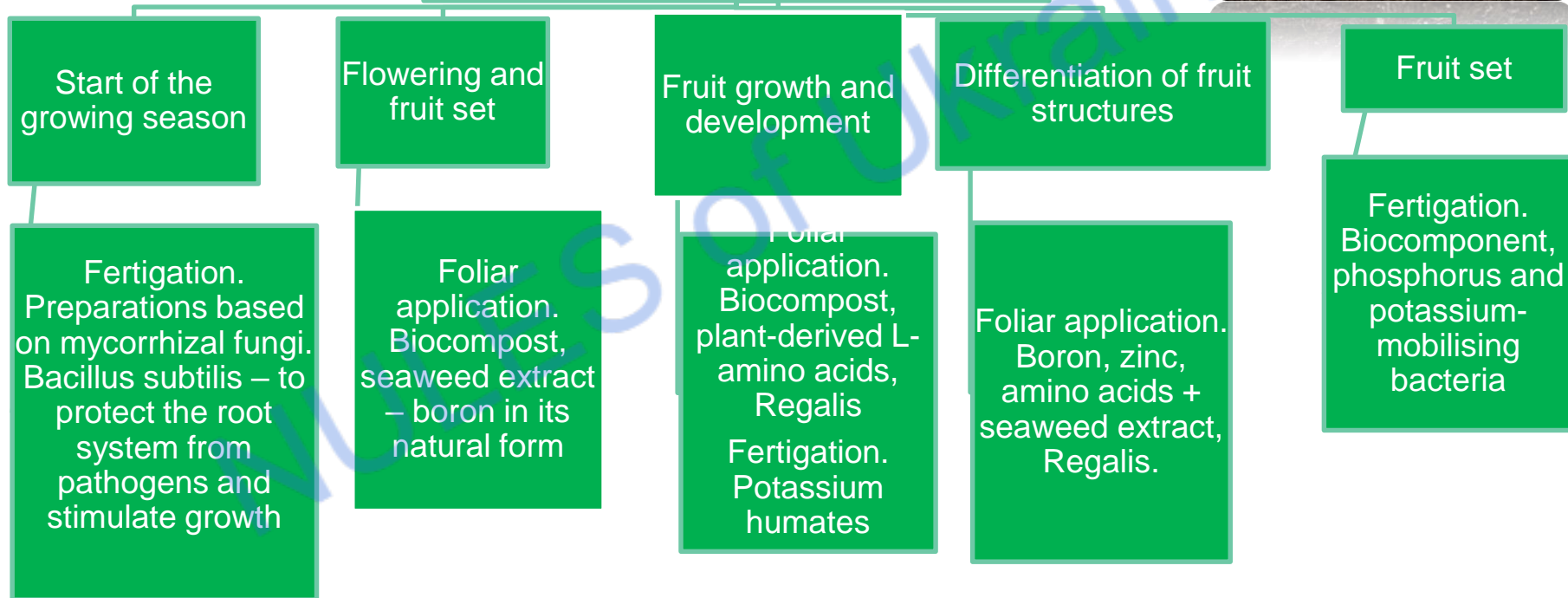
Effect: Instead of a single sharp release of salts (which can 'burn' the roots in dry soil), the fertiliser is released in small portions over a period of 3–6 months.



The cost of organic fertilisers depends on the type of product and the scale of the farm. These products can be cheaper than their chemical equivalents in the long term



APPLE TREE FERTILISATION SYSTEM



FEATURES OF SHAPING AND PRUNING OF AN APPLE ORCHARD



Forming low-volume crowns

Dwarf rootstock (M.9), narrow-row orchard

French Axe, reducing the crown volume by 60–70% compared to traditional forms, facilitates ventilation and rapid drying of leaves after dew (prevention of fungal diseases that become active in warm, humid conditions)

Slender spindle (Spindle) with an emphasis on short, overhanging twigs, allowing the tree to distribute moisture more efficiently in conditions of water scarcity

Adaptation to water scarcity: Pruning has a direct impact on a tree's water balance

Reducing the evaporation area: More radical rejuvenation pruning during dry years helps the tree survive by reducing the volume of vegetative mass that the roots must supply with water

Apple fruits are harvested when they reach harvest maturity, in dry weather and during the cooler part of the day

Methods of determining ripeness – visual, chemical, instrumental and computational (non-destructive: using near-infrared spectroscopy; chlorophyll sensors, hyperspectral cameras)

Harvesting sequence: collection of fallen fruit; apples from the lower branches, followed by those from the top of the tree. The apple must have its stalk intact and must not be mechanically damaged

Containers for harvesting apples – fruit-picking bags, canvas buckets with detachable bases or other containers that prevent mechanical damage, with a capacity of 10–15 kg
The fruit is then carefully transferred to containers with a capacity of 200–400 kg
Number of containers on the container truck: 6–8

Within 24 hours of harvesting, the apples must be cooled to 1–4 °C



The **Pluk-O-Trak Senior** semi-mechanised apple harvesting system is suitable for orchards with row spacings of 3.5–5.0 m and tree heights of up to 4.0 m. It can be used effectively on hilly, sandy and rocky terrain



The self-propelled platform with a **Welding Corp** vacuum harvester reduces the workload on pickers and increases labour efficiency. To minimise damage to the apples, the system features a small scoop-shaped inlet through which the fruit is sucked in one by one, preventing contact between the fruit before it enters the container



Frumaco Tecnofruit CF 105 self-propelled model for intensive orchards; it can operate on slopes and wet ground, minimising mechanical damage to the fruit thanks to an individual conveyor belt for each worker



SUMMARY: APPLE ORCHARDS IN THE NEW CLIMATIC REALITY

Climate resilience: prioritising a range of varieties adapted to temperature stresses and water shortages

Technological modernisation: transition to intensive management systems with automated microclimate monitoring

Eco-innovations: the introduction of **green ammonia** as the foundation for decarbonisation and sustainable orchard management



Thank you for
your attention!



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