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FAO PLANT PRODUCTION AND PROTECTION PAPER

230

Good Agricultural Practices for greenhouse vegetable production in the South East European countries

Principles for sustainable intensification of smallholder farms

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Contents

9. Early potato

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ABSTRACT

The harvest area of potatoes in South East Europe is about 580 000 ha with a production of about 11 000 000 tonnes. It is estimated that 20–25% of all harvested area is used for early potatoes. Early potato is of high biological and nutritional value, and is suitable for growing on small family-run commercial farms. In the continental area of South and South East Europe, new potato matures for harvest in late May, June and early July. In recent years, early potato has reached the market 20–25 days earlier thanks to the adoption of specific cultivation practices and growing technologies, as well as an increase in financial input per unit area. As the first spring vegetable, early potato is considered a supreme biological and economic crop. The first precondition for high, stable and quality production of early potato is the choice of very early-maturing cultivars with high yield potential, good adaptability and stability. The second precondition is the planting of equally sprouted and certified seedlings with mulching and crop covering with agrotextiles. In the continental area of South and South East Europe, apart from early potato farming in temporary protected areas – for example, direct crop covering with or without mulching and in low plastic tunnels – early potato is also grown in large plastic tunnels without additional heating. Early potato is planted in mid-February in the Mediterranean area. This is 30 days earlier than in the continental area, and when covered with agrotextiles it can be harvested even earlier. This chapter presents some biological and agrotechnological aspects, such as biological needs, fertilization, irrigation, harvesting and storage of early potatoes.

INTRODUCTION

The potato crop area in South East Europe (SEE) is about 580 000 ha with a production of about 11 000 000 tonnes (FAOSTAT, 2013). An estimated 20–25% of all potato-growing areas are intended for early potatoes. In addition to conventional production, early potato is grown in temporary and permanent protected areas.

Early potato is of high biological and nutritional value, and is suitable for growing on small-scale family-run greenhouse farms. When cultivation adheres to good agricultural practice (GAP) guidelines, the crop is of agronomical, agrotechnical, biological, environmental and especially economic importance.

ENVIRONMENTAL REQUIREMENTS

Potato is a widely distributed crop owing to its extreme adaptability and stability; it can be grown on various soils and in a range of climates (Ilin *et al*., 2000b). Several authors report that early potato has moderate temperature requirements. Above-ground plant parts can sustain low temperatures of between –1 and –1.5 °C for short periods. Late spring frosts (≤ –2 °C for long periods) damage delicate foliage, and represent a hindrance to cropping in continental SEE (Plate 1). On the other hand, temperatures in Mediterranean climate regions rarely fall below 0 °C, and temporary protected areas (agrotextile covering) provide adequate protection. When large tubers are planted, stems and foliage sometimes rebound from secondary buds; early potato then reaches the market with a delay of 15–25 days, coinciding with early potatoes conventionally grown without pre-sprouting. The increased supply causes prices to fall, reducing profitability per unit area.

The minimum soil temperature for successful potato sprouting and emergence is 7–10 °C; however, the optimum temperature is much higher at 14–16 °C or even 18–25 °C (Table 1). Under optimal soil moisture conditions, early potato sprouts emerge at the following soil temperatures:

- 7–10 °C, in 30–35 days
- 10–12 °C, in 25–27 days
- 14–16 °C, in 18–22 days
- 18–25 °C in 12–13 days
- 27–28 °C in 16–17 days

ILIN

Plate 1
Negative effect of low temperatures when early potato starts to emerge

When pre-sprouted tubers are planted, emergence is 6–10 days earlier under the same environmental conditions. The root system forms at soil temperatures > 7 °C. Potato must root as early and as firmly as possible, as young, well-rooted plants are more tolerant to drought, nutrient uptake is better and above-ground growth more intense. Above-ground plant parts and tubers form at 15–20 °C. Optimum temperature for intensive tuber bulking is 16–19 °C. Soil temperatures > 20 °C slow tuber bulking, 29–30 °C abruptly decrease yields and tuber growth stops, while > 42 °C plants die (Table 1).

TABLE 1
Effect of temperature on growth and development of early potato (°C)

Critical minimum air temperature	Minimum soil temperature for germination and emergence	Optimum soil temperature for germination and emergence	Optimum air temperature for vegetative growth	Optimum soil temperature for tuber formation	Growth and development stop	Growing period ends
–2	7–10	14–16 (18–25)	15–20	16–19	29–30	> 42

Early potato also has moderate requirements regarding air relative humidity; optimum air humidity is 75–80% (Ilin *et al*., 2002). Early potato prefers warm, light to medium-heavy soils, deep and fertile with favourable physical and chemical properties. Early potato cultivation is not recommended on moist, poorly-drained, cold and heavy clay soils.

SOIL REQUIREMENTS

Early potatoes grow on most soils, but when harvesting is done mechanically, harvesting under adverse weather conditions is easier in lighter and medium-bodied soils. Potatoes grow on both organic and mineral soils. The minimum pH requirement is 5.5, and a pH of < 4.8 leads to impaired growth. Alkaline conditions can have a negative impact on skin quality and highly alkaline conditions can induce micronutrient deficiencies. For mineral soils, the general recommendation is a pH of 6.0–7.0.

METHODS OF EARLY POTATO PRODUCTION IN GREENHOUSES

Early potatoes are produced in the open field using standard technologies. The time of removal of early potatoes depends on the earliness of the particular variety and whether or not the planting material was sprouted before planting. A relatively new technology is early potato production in protected areas – temporary (Plate 2) and permanent (Plate 3):

ILIN

Plate 2
Temporary protected area

BUGARČIĆ

Plate 3
Permanent protected area

- **Temporary protection** – plants are uncovered immediately before extracting the young potatoes. Techniques include agrotextile coverings with or without soil black film mulching, and low and semi-high plastic tunnels from which the plastic film is removed before harvesting the young tubers.
- **Permanent protection** – the crop is grown in high plastic tunnel greenhouses of dimensions: height 3.6–4.2 m, length ≤ 8 m, width 5–6 m.

EARLY POTATO PRODUCTION TECHNOLOGIES

Quality of seed potatoes

Physiologically young seed potato gives a smaller number of sprouts than physiologically mature, resulting in fewer initiated tubers. Additionally, appearance of a single sprout on the top of the tuber during germination is another reliable indicator that the seed is physiologically young. This is called apical dominance, and removal of the apical bud stimulates sprouting from other dormant eyes, which will significantly increase the number of stems, stolons and tubers per seed potato. Physiologically old, or senile, seed potato is of low potential biological value and should not be used for further reproduction. If for any reason farmers decide to do so without pre-sprouting the tubers, they will also keep unwanted hair sprout tubers. Some tubers may even become knobby. Planting physiologically old seed potatoes, results in slow emergence and growth of the stems and foliage. Such plants develop poorly and this ultimately results in a serious drop in yield (Plate 4). Therefore, only physiologically mature certified virus-free seed potatoes should be planted.

Pre-sprouting seed potatoes

In early potato farming, the tubers are allowed to sprout before they are planted. It is important that the sprouts do not grow too fast and long, which would make them susceptible to breakage during handling. Therefore, they are left in well-ventilated areas exposed to diffuse light, temperatures of 12–15 °C and relative humidity of 85–90%. Pre-sprouting speeds up physiological and biochemical processes within the tuber and increases the quantity of nutrients around the buds. Sprouts will then quickly start to grow, first from the main bud

Plate 4
Physiologically young seed with evident apical dominance (left); hair sprout tubers of low potential biological value (centre); physiologically old seed with knobby tubers of very low biological potential value (right)

and subsequently from several lateral buds, extracting nutrients from the parent tuber's reserve. The planted potato lives on its own for a while; water and nutrient uptake from the soil solution commences once the plant has rooted.

NTI

Plate 5
Physiologically mature and certified seed tubers with quality germination

For early potato production in plastic tunnels, pre-sprouting takes place in November and December, and under direct covering (agrotextile) in December or January. The practice takes 30–60 days (30–35 days for very early and early cultivars, 35–40 days for medium-early cultivars, ≤ 60 days for medium-late cultivars). Sprouting seed potatoes should be checked 2–3 times, and damaged or diseased tubers discarded, especially those with weak, elongated and hairy sprouts. The optimum temperature is 18–20 °C over a period of 7–10 days for all buds on a tuber to break dormancy. Quality sprouted tubers have short (0.5–1.5–2.0 cm), stout, tough, green or purple sprouts (Plate 5). Pre-sprouted potatoes emerge 10–15 days earlier and plants grow stronger and mature 2–4 weeks before non-sprouted ones (Ilin *et al*., 2002).

Crop rotation

Early potato is the first crop in rotation and should be fertilized with manure. Previous crops include any legumes, spinach and winter lettuce. Thanks to the early harvest, cover crops grow successfully in the same season with a very low investment input. Soon after harvest, the soil is tilled for the cover crop (e.g. cabbage, cauliflower, kale, Brussels sprouts, kohlrabi, beet, cucumber, gherkin, green beans and sweetcorn). Potato is a good preceding crop for all vegetables – with the exception of tomato and eggplant. Note that it should not be planted on the same spot for at least 4 years.

Soil preparation

Seedbed preparation starts at the end of the previous season when harvest residues are removed by disking or shallow ploughing. Primary tillage is performed to a depth of 30–35 cm in the autumn, and then pre-plant tillage is done in the early spring as soon as the soil moisture conditions are appropriate.

Planting early potatoes

It is recommended to use only healthy and certified seed potatoes. Small tubers saved from the previous season should not be used due to potential virus threats (causing ≤ 60% yield loss) and the likelihood of environmental and age-induced degeneration. High-quality seed potatoes grow tough and stout sprouts, sprouting

and emergence both occur quickly, and both above-ground plant growth and tuber development are intense. Early cultivars initiate tubers 10–15 days after the emergence of sprouts from the soil. When early potatoes are cultivated with mulching and direct agrotextile covering, the crop is ready for harvest 55–60 days after planting; in plastic tunnels, harvest takes place around 50 days after planting.

The size of the early potato seed bed depends on the earliness of the particular cultivar. Very early and early cultivars are usually planted at 60–70 × 23–25 cm, and medium early at 60–70 × 27–30 cm with a planting depth of 6–10 cm. The quantity of seed potatoes to be planted depends on the tuber size. Generally, tubers for planting are 50–60–70 g in weight and 28–55 mm in diameter (more often 35–55 mm). A crop area of 1 ha is planted with 2 400–3 000 kg of seed potatoes. On smaller areas, planting is done manually. In temporary protected areas, 4-row semi-automatic planters are used; in plastic tunnels > 3.6 m high and 8 m wide, 2-row planters are usually used.

Mulching foil

Mulching is an old cultivation practice used to prevent weed growth, retain soil moisture, increase soil temperature, and promote microbiological activity and mineralization of organic matter in soil. When mulching foil is applied, early potatoes can be harvested ≤ 10 days earlier. When using mulch foil in the early potato emergence stage, note: first, that all stems must emerge from the soil and foil and, second, that frost has a greater impact on soil covered with mulch foil. It is, therefore, important to combine mulching with direct crop covering using agrotextile. Before harvesting, the mulch foil is removed manually or mechanically and recycled.

Agrotextile coverings

Agrotextiles are an important tool in early potato farming. Polypropylene synthetic materials made from continuous poly propionic fibres are appropriate. There are a range of materials available on the market with various trade names but the same basic properties. Agrotextile provides favourable microclimatic conditions for crops, allowing the transmission of light, air and water. It is very lightweight (17–60 g m^{-2}) and highly elastic, easy to handle and apply. The pressure exerted on the plants is virtually the same as that applied by a dew drop (10–17 g m^{-2}). Adoption of agrotextile brings many **benefits**:

- Minimal temperature fluctuations – soil and plants are heated under the fabric during the day, while at night they cool gradually.
- Uniform water distribution to plants and soil – drops of water from irrigation or rainfall permeate the micro-openings in the fabric.
- No crust formation – the soil dries gradually.
- Avoidance of condensation – there is continuous evaporation through the micro-openings and when the temperature drops, the water in the openings

forms a thin layer of ice, releasing energy and preventing the plant organ damage typical of cold weather.

- Good protection from heat – the white material reflects direct sunlight.
- Protection from adverse effects of wind and hail (Plate 6).
- Physical barrier against harmful insects and diseases.

When handled and used with care, agrotextile can be used for 2–3 years. It is UV-stabilized, easily recycled and comes in various widths (1.2–12.75 m) and lengths (100–500 m).[1]


NITI

Plate 6
Protecting early potatoes from hail

Irrigation requirements

Potatoes favour cold and humid weather. During the initial stages of growth and development, immediately after emergence and in the rooting phase, potato has low water requirements. As stems and foliage grow, water requirements increase, peaking during flowering and tuber bulking. The lower limit of optimum soil moisture for successful early potato farming is 70–80% of field water capacity. Early potato loses 260–280 mm of water through evapotranspiration during the growing season – i.e. the exact quantity of water needed for successful early potato farming. In a dry spring, there is usually a rainfall deficit (40–60 mm); in an extremely dry spring, the deficit can reach as much as 120–160 mm. This lack of rainfall should be compensated for by 1–4 watering treatments (Plate 7). Timely irrigation increases early potato yield by 30% on average (Ilin *et al*., 2000b, 2002; Maksimović and Ilin, 2012).

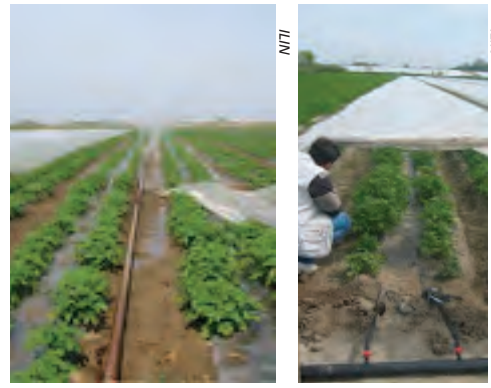
NITI NITI

Plate 7
Sprinkler irrigation of early potato (left)
Fertigation of early potato in temporary protected area with agrotextile cover (right)

[1] See Part II, Chapter 1.

Fertilization

Fertilizer application depends on various factors, including:

- specified nutrient content – primarily nitrogen using the N-min method;
- crop nutrient removal rates per unit of yield (tuber, stem and leaf);
- planned or desired yield; and
- N quantity released through mineralization during crop growth.

There is high positive correlation between early potato yield and irrigation on the one hand, and mineral N from mineral and organic fertilizers on the other hand (Ilin *et al*., 2002). Fertilization has a significant effect on both yield and quality. Under no-irrigation conditions, a 10-tonne yield of early potato tubers removes 30.2 kg N, 4.7 kg P and 31.4 kg K on average. Under irrigation, a 10-tonne yield removes 28.7 kg N, 4.7 kg P and 30 kg K. Optimum results are achieved when early potato is fertilized with 40 tonnes ha^{-1} manure + $N_{80}P_{80}K_{80}$ (Ilin *et al*., 2002). Similar recommendations for early potato were published in France: $N_{120–150}P_{100–150}K_{200–250}$ (Wichmann, 1992). These recommendations for nutrients, especially nitrogen, comply with the EU Directive (Council Directive 91/676/EEC of 12 December 1991, Article 5, 4).

The whole amount of organic fertilizer, plus one-quarter to one-third nitrogen, and two-thirds P_2O_5 and K_2O, are applied during basic tillage. The remaining quantities are mixed into the soil before planting. In a **temporary protected area**, the whole amount of organic fertilizer, plus one-third to one-half NPK fertilizer, are applied during basic tillage, and the rest in 3–4 treatments via fertigation at 15-day intervals (Plate 7). In a t**unnel-type protected area**, organic fertilizers are applied during basic tillage (4 kg manure m^{-2}), and the whole amount of NPK fertilizer is applied through fertigation in five equal treatments at 10-day intervals.

PHYSIOLOGICAL DISORDERS, PESTS AND DISEASES

At physiological maturity, potatoes register numerous causal agents: *Phytophthora infestans*, *Alternaria solani*, *Rhizoctonia solani*, *Verticillium dahlia*, *Sclerotinia sclerotiorum*, *Pithium species*, *Helminthosporium solani*, *Spongospora subterranean* subsp. *subterranean*, *Colletotrichum coccodes*, *Streptomyces scabies*, *Erwinia carotovora* subsp. *carotovora*, *Erwinia carotovora* subsp. *atroseptica*, *Clavibacter michiganensis* subsp. *sepedonicus*, *Phytoplasma*. There is widespread occurrence of numerous pests: *Leptinotarsa decemlineata*, *Myzus persicae*, *Macrosiphum euphorbiae*, *Circulifer tenellus*, *Tetranichus urticae.*

Given the early yield of young potato, physiological disorders in the tubers are generally avoided, although there can be sporadic occurrence of macro and micro element deficits in light, sandy soils or when there is inadequate fertilization with organic and mineral fertilizers. Most viruses are the result of degeneration due to successive years of farmers using their own, virus-infected, planting material.

TABLE 2
Identification and control of the most common early potato disorders, deficiencies and diseases

Symptoms	Reasons	Prevention and control measures
Tuber physiological disorders		
Sprouts developed from apical buds on young tuber due to high temperatures and temperature fluctuations	Heat sprouting/ young tuber chaining	Avoid environmental stress Adopt proper planting, hilling, fertility and irrigation practices to encourage uniform vine and tuber growth
Formation of knobs when secondary growth occurs at lateral eyes on young tuber due to loss of apical dominance	Knobby tubers	Avoid major fluctuations in nitrogen availability Maintain available soil water content > 70%
Growth cracks caused by irregularities in young tuber growth in response to fluctuating water supply	Tuber cracking	Maintain uniform, adequate soil moisture and nutrient levels throughout tuber bulking
Nutritional balance		
Plant stunted and older Lower leaves light green	N deficiency	Apply optimal fertilization
Formation of lush vegetative mass Plants sensitive to disease Small numbers of fine young tubers formed Pollution of environment	N excess	Apply optimal fertilization
Plants remaining in growth phase Maturation process delayed Stem, leaf veins and petioles turning purple	P deficiency	Apply appropriate fertilization
Plants intoxicated Pollution of environment	P excess	Apply optimal fertilization
Burning and drying of leaf edges	K deficiency	Apply appropriate fertilization
Chlorosis between leaf veins	Mg deficiency	Apply appropriate fertilization
Diseases		
Mild mosaic with poorly expressed enrollment or deformity of leaves (depending on strain of virus and susceptibility of variety)	Potato virus X (PVX)	Plant certified seed
Extremely mild mosaic Expressed necrosis of leaves (depending on strain and variety)	Potato viruses Y and A (PVY, PVA)	Plant certified seed
Potato leaf roll/tuber necrosis Twisting of upper youngest leaves Leaves erect, brightly coloured, base or margin (depending on variety) indigo or reddish Most prominent symptoms in plants with secondary, chronic infection	Potato leaf roll virus (PLRV)	Plant certified seed
Twisting of leaves, leaf margin chlorosis (symptoms of primary infection and most common) Mosaic, deformation and bright colour of leaves Necrosis of petiole leaves and stems, even stunting of plants (depending on variety)	Potato virus M (PVM)	Plant certified seed
No or very mild symptoms Light mosaic during growing season, withdrawing and becoming masked Leaves slightly lighter and no change in general appearance of plants	Potato virus S (PVS)	Plant certified seed

Early potatoes can be infected by many different viruses, resulting in low yield and reduced tuber quality. Viruses that have the greatest impact on young potato production include the luteoviruses (PLRV), potyviruses (PVA, PVV, PVY), potexviruses (PVX) and carlaviruses (PVM, PVS). A diagnosis is often possible from the symptoms, which include mosaic patterns on leaves, stunting of the plant, and leaf or tuber malformations. However, symptoms are not always visible, due to interactions between the virus and the potato plant, growing conditions (e.g. fertilization, climate conditions) or the age of the plant when it is infected.

In addition to the most harmful and widespread diseases, PVY and PLRV, there is incidence of other potato viruses in Serbia and SEE: potato virus X (PVX), potato virus S (PVS), potato virus M (PVM), potato virus A (PVA) and potato aucuba mosaic virus (PAMV). In addition, tomato spotted wilt virus (TSWV) is a potential threat to potato production in Serbia and SEE (Krstić, 2014, 2015).

BUGARČIĆ

Plate 8
Removing the plastic foil from plastic low tunnel-type and sprinkle irrigation of crops before early potato harvest

GAVRILOVIĆ

Plate 9
Early potato grown in high plastic tunnel

EARLY POTATO HARVEST

Early potatoes are obtained from early varieties or are harvested at the beginning of the season in the country of origin. "Early potatoes" have the following characteristics (UNECE STANDARD FFV- 52, 2009):

- harvested before complete maturity;
- marketed immediately after harvest; and
- skin easily removed without peeling.

In the SEE region, early potato is harvested and marketed from late March to early July. In Mediterranean climate areas, harvest begins in late March or early April. In continental areas, early potato is cultivated in tunnels (Plates 8 and 9) and can be harvested from 20 April; if grown in temporary protected areas, harvest is 5–15 May. Conventionally farmed early potato without pre-sprouting is harvested around 10 June. The yield of early potato depends on the cultivation practices, cropping system and harvest date, but is usually 10–15 tonnes ha^{-1}, with each plant yielding 200–300 g (Ilin *et al*., 2002). Prior to harvest, the agrotextile is removed, above-ground plant parts discarded, and

the mulch foil lifted either manually or mechanically. After harvest, early potato tubers are gathered, washed, packed and marketed (Plate 10).

STORAGE

The tubers are harvested with a soft, thin and immature skin that rubs off easily. Care must be taken during harvest, washing, packing and distribution to green markets and stores, because young tubers are susceptible to damage. Early potatoes have relatively high water content and a significantly lower dry matter content than physiologically mature potato tubers. The respiration rate of immature tubers at harvest is about four to five times greater than that of mature tubers. To minimize losses due to respiration, early potatoes are usually stored briefly in refrigerator cars without controlled atmosphere. They can also be stored for short periods on family farms before transportation or in cold storage areas of mini- and mega-market stores prior to display and selling. The ideal short-term storage temperature is 4 °C. Inappropriate storage conditions lead to rapid deterioration of quality (within a few days).


NITI

Plate 10
Early potato sold at green market

Early potatoes are SAFE for consumption – NO PESTICIDES are used.

Early potatoes ensure CONTINUITY in the supply to consumers until potatoes from conventional production in open fields are harvested.

GAP recommendations – Early potato production

Permanent protection – the most expensive, but the safest system for early production – high plastic tunnel without additional heating and cooling.

Temporary protection – mostly uniform large young tubers, but moderate yields – mulched soil with or without agrotextile cover.

- Use quality, certified, virus-free planting material.
- Check seed potatoes for sprouting and remove damaged or diseased tubers, especially those with weak, elongated and hairy sprouts (usually infected by viruses).
- Maintain ideal conditions for germination:
  - first 7–10 days 18 °C, thereafter 12–15 °C;
  - diffuse light;
  - relative humidity 85–90%.

- Apply organic fertilizers manufactured and managed on farms. Alternatively, use industrially-manufactured pelleted or granulated bio-organic fertilizers. For optimum yield, apply a rate of 40 tonnes ha^{-1} manure + $N_{80}P_{80}K_{80}$ at appropriate intervals:
- In temporary protected area – the whole amount of organic fertilizer and one-third to one-half of NPK fertilizer during basic tillage, the rest in 3–4 treatments through fertigation at 15-day intervals.
- In tunnel-type protected area – organic fertilizers during basic tillage and the whole amount of NPK fertilizer through fertigation in five equal treatments at 10-day intervals.
- Apply optimum planting distances:
  - very early and early cultivars – 60–70 × 23–25 cm
  - medium-early cultivars – 60–70 × 27–30 cm

- Plant at optimum depth of 6–10 cm.
- Maintain optimum soil moisture of 70–80% of field water capacity.
- Harvest early potatoes before they are completely mature and market immediately.
- Store at an ideal temperature of 4 °C to avoid quality deterioration within a few days.

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