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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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6. Root and onion vegetables

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ABSTRACT

Traditional greenhouse vegetables, such as tomatoes, cucumbers and lettuce, are common vegetables found almost year-round in supermarkets. Improved quality of life and consumer buying capacity have increased the demand for other commodities, including herbs, roots, tubers, green onions and exotic vegetables. Production practices and technologies for growing less common greenhouse root and onion vegetables are presented to growers in an easily understandable manner. Greenhouse radish, carrot, onion and garlic for green-leaf market-oriented production are included. Guidelines are provided on technologies for growing roots and onions for green leaves in different crop protected cultivation constructions, including greenhouses, tunnels, low tunnels and fields covered with agrotextile materials for temporary frost protection.

RADISH

Introduction

Radish (*Raphanus sativus* L. var. *sativus*) most likely originated in the area between the Mediterranean and the Caspian Sea. Radish is grown mainly for its thickened fleshy root. Small radish is pungent; it is eaten fresh as an appetizer and used to add colour to dishes. Currently radish is a minor crop and markets are quite limited.

Environmental requirements

Radish is a quick-growing, fast-maturing, cool-season root vegetable. The seed germinates in 3–4 days in moist soil at optimum soil temperatures of 18–25 °C. In winter, germination can take 5–6 days. The minimum temperature for germination is 5 °C. The germination rate declines when soil temperature is < 13 °C. Once the plant has germinated, maintain the air temperature in the greenhouse at 8–10 °C for 5–7 days to prevent plant elongation. During the remaining growing period, optimum air temperatures are: during the day, 12–14 °C (when cloudy) and 16–18 °C (when sunny); at night, 8–10 °C. During the growing period, optimum

soil temperature is 12–16 °C to ensure the best quality and root shape. The roots of globe varieties tend to elongate and develop a poor shape in hot weather. Radish is a long-day crop; therefore, on short days it forms good quality roots. Long days can induce flowering or bolting (development of seed stalks); in combination with warm weather, the seed stalk may develop so rapidly that no edible root is formed. Radish becomes more pungent in hot weather.

Variety selection

Commercial seed companies offer a wide range of varieties. Most commercial radish varieties for greenhouse production are round, but they may also be ovoid, cylindrical or turnip-shaped. They can be red, white or a combination of red and white colours, such as pink or purple. Red varieties are the most in demand on the market. The best varieties for out-of-season production in greenhouses or tunnels are early varieties (20–22 days to maturity), with tolerance to light deficiency, bolting and cracking, and adapted to form roots under low temperature conditions, with relatively short lives and firm roots. When selecting a radish variety, growers should consult the national registration catalogue of varieties to check which varieties are recommended for their specific conditions. For EU countries, growers should refer to the Plant Varieties Database, which lists over 300 EU-registered radish varieties for both outdoor and greenhouse production.[1] For the identification of suitable cultivars, refer to FAO's Hortivar database.[2]

Growing technologies

The quantity and quality of the radish yield must be sufficient to justify the expense of indoor production. The growing medium is, therefore, very important. There are two main approaches:

- In-ground culture (Didiv *et al*., 2015) – applied when radish is grown in low tunnels and plastic-covered greenhouses (Plate 1).
- Container culture (organic substrate or soilless) – more common in intensive production in glass greenhouses.

Soil culture

A greenhouse may be erected on quality field soil, which then serves as a media for growing radish. Prepare the soil carefully and amend with organic matter (e.g. well-made compost). Avoid fresh manure, as it can provide excess ammonia and a high content of nitrates in the radish root.

[1] Available at http://ec.europa.eu/food/plant/plant_propagation_material/plant_variety_catalogues_databases/search/public/index.cfm.

[2] Available at www.fao.org/hortivar.


GHIZZI

Plate 1
Greenhouse radish; in-ground culture


ROSCA

Plate 2
Soil preparation with a rotary tiller

Soil preparation

Proper soil management is key to the sustainable production of radish in the greenhouse. When using an in-ground method for the production of radish, avoid the soil compaction that typically occurs during greenhouse construction, through inappropriate use of agricultural equipment, or as a result of frequent or heavy traffic of machines. Soil compaction can increase soil density in surface horizons, with a negative impact on plant growth and yield. Heavy, poorly drained soils are not recommended for radish production.

On sites with compacted soil or poor fertility, make raised beds. Prepare the soil to a fine texture prior to seeding to obtain uniform shape of radish roots. Level the soil surface to ensure uniform depth of sowing. Soil requires good aeration and water management. Radish does not require deep soil preparation. Prepare the soil using rotary harrow or rotary tillers (Plate 2).

Seeds and planting

The 1 000-seed weight of radish is 8–12 g. For accurate spacing of radish plants in the greenhouse, use sized seeds and precision seeders. For indoor production, use large seeds, as they have high germination energy ensuring early plant establishment. Sow with hand seeders or pneumatic precision seeders, either pulled by tractor or professional engine-run (Plate 3).


ORTOLANDA

Plate 3
Pneumatic seeder

Seeds should be graded and treated prior to planting. Use seeds with a diameter > 2.5 mm at a rate of 2.5–3.5 g (300–400 seeds) m^{-2}. Seeding depth is 0.5–1.0 cm,

the space between rows 10–20 cm (or as specified by the seeding equipment) and the space between plants 2–4 cm. At 7–8 days after plant emergence, if plant density is too high, remove poorly developed plants. In the winter, when light intensity is low, reduce density to 250–270 plants m^{-2}; in February–March, increase plant density to 300–350 plants m^{-2}. When buying seeds, consult the seed supplier catalogue and check for specific variety recommendations on plant density and plant spacing – they may differ from conventional recommendations. Plant density must be no greater than the recommended level, especially in a season with light deficiency, as it would affect the quality of the harvest.

When growing radish in fields covered with agrotextile materials, sow seeds as soon as the soil is workable. Spring frosts – even snowfalls – do not usually injure radish crops after plants have emerged under the temporary covers of agrotextile materials. For greenhouse radish, sowing should take place at 10–12-day intervals to ensure a continuous supply of fresh roots to the market.

Irrigation

Before plant emergence, do not irrigate soil in the greenhouse. Radish requires frequent (once every 2 or 3 days) and uniform irrigation for optimal growth and good root shape. Excessive irrigation combined with high nutrient content in the soil leads to to vigorous growth. On the other hand, if the soil is allowed to dry out, radish becomes woody, with a poor texture and taste. After irrigation, ventilate the greenhouse. Control the humidity and avoid fluctuations in temperature in order to prevent plant infections and prevent the radish from splitting or cracking easily.

Fertilization

During the short period of vegetation, radish takes up a high quantity of nutrients. Given the high level of nutrient consumption, a low level of nutrients in the in-ground culture immediately affects both yield and quality of the radish root. Optimize and maintain the supply of nutrients to encourage good production and harvest quality (Rosca and Patron, 1985). Any deficiency of nutrients in the growing media affects plant growth; apply any fertilizers required before seeding. In greenhouses where a watering boom or other sprinkler system is used for irrigation, apply soluble fertilizers with irrigation.

Greenhouse soils amended with compost or manure may not require additional fertilization for good radish plant growth. In soils with low levels of nutrients, application of mineral fertilizers gives good results in terms of both yield and quality. Avoid over-fertilization when growing radish in the greenhouse, as – combined with low light intensity – it can increase the level of nitrates in the radish product.

Pest and disease control

Radish is generally trouble-free. There are no herbicides registered for use on radish to control weeds. In case of pest emergence, adopt biological, mechanical or IPM methods, but pay attention to the timing specifications: most pesticides require a long waiting period before harvest, while radish has a short growth period (Table 3).

Harvesting and post-harvest handling

The average yield is 1.5–3.5 kg m^{-2}; it varies according to the season, variety, substrate and growing conditions. Radish in the greenhouse can be harvested manually or with harvesting machines. Regardless of the method adopted, the necessary harvesting and handling operations are: pulling and bunching, topping, washing, grading and packing (Plate 4).

Bunching is frequently done in the greenhouse when pulling plants, especially for produce destined for the local market. Globular-rooted varieties are tied in bunches of 10–15 plants, and the bunches are packed in plastic and wooden crates. Topped radish is washed and packed in plastic bags and transparent clamshells. For long-distance shipment, radishes are shipped under refrigeration. The recommended short-term storage temperature is 0 °C with a relative humidity of 95–100%. Topped radish packaged in perforated plastic bags keeps for 3–4 weeks. Bunched radish keeps for 1–2 weeks.

Container culture

This system employs plug trays traditionally used for growing vegetable transplants (Plate 5). The most common are plastic trays with an external size of 40 × 40 cm, comprising 64 plug cells of 5 × 5 × 5 cm. The cell size must be sufficient to ensure good plant growth.

Various growing media may be used in container culture, but they must allow for adequate drainage. The most common media are: peat; peat mixed with organic ingredients; and inorganic substrates. Once plants are well established, supply additional nutrients to sustain crop growth.

Plate 4
Radish: harvesting and bunching (left); washing (centre); packed bunches ready for delivery (right)


ROSCA

Plate 5
Dibbling tray cells


ROSCA

Plate 6
Seeding in plug trays

Wash and disinfect the trays before filling with substrate for growing vegetable transplants. Use a dibbler to make a 0.5–1.0-cm hole in each cell (Plate 5) and plant one seed per cell (Plate 6).

The trays can then be placed on the soil in the greenhouse, but the hydroponic method is increasingly adopted, with trays placed on benches especially arranged for flood and drain irrigation. If available, first put the trays in a germination room for 1–2 days at 18–20 °C. The first flood irrigation is carried out 6–7 days after seeding in trays, when the first plant root exits the tray through the drainage hole. Flood irrigation lasts about 20 minutes. The water level in the seeded tray should not exceed 1 cm (Plate 7).

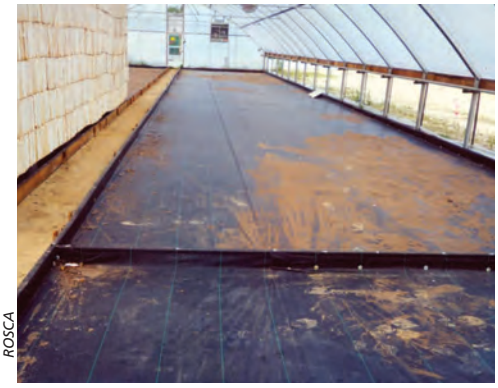
ROSCA

Plate 7
Greenhouse prepared plug system with flood irrigation

During the growing season, trays are flooded daily – if necessary, twice a day. As required, inject soluble fertilizers into the irrigation water, adjusting the input to meet the needs of the plants. The environmental conditions (temperature, air and soil moisture, lighting) and harvesting operations are similar to those for in-ground culture.

CARROTS

Introduction

Carrots (*Daucus carota* L. var. *sativus*) are typically grown as an open-field crop, but gardeners grow carrots also in greenhouses and other indoor constructions to supply the market with early season bunched roots, when there is high demand for fresh vegetables following a long winter season. Carrots come in a variety of shapes, sizes and colours, including orange, yellow, pink, red and purple. With the right varieties and methods, it is possible to have fresh and ready young roots of carrots for cooking and snacking at any time. Carrots can be grown in a greenhouse throughout winter for a spring crop, but they cannot be grown in the greenhouse in late spring and summer as they prefer cool conditions. Solar tunnels and greenhouses, as well as low tunnels, are suitable for growing early carrots.

Environmental requirements

Carrots are a cool season crop and are somewhat frost tolerant; nevertheless, seedlings of ≤ 6 leaves cannot withstand hard freezes. Root growth is fastest at 15–18 °C, while the optimum temperature for seed germination is 18–20 °C. Carrot seeds can germinate at low soil temperatures, but the germination period is shorter at higher temperatures. For example:

- < 5 °C, carrots struggle to germinate.
- < 10 °C, carrots germinate slowly, taking 25–30 days to reach plant emergence.
- ≥ 10 °C, germination occurs after 8–10 days.

The recommended soil temperature for germination is, therefore, ≥ 10 °C.

Carrots have high light requirements and indoor production in November–January is difficult, due to lower light intensity. The greenhouse must be on an open sunny site for early carrots. Carrots like well-drained, fertile soils rich in organic matter. Sandy peat soils provide the best conditions for deep penetration and the formation of uniform roots. The pH value should be 6.5–7.5.

Cultivar selection

There are two main groups of cultivated carrots: the Eastern (anthocyanin) and the Western (carotene) carrot. For indoor production, carotene varieties are recommended, in particular the early varieties, ‘Nantes’ and ‘Amsterdam’ – small, slender, finger-shaped carrots, fast-maturing and adapted as early crops in cold frames, tunnels and greenhouses. Other common varieties are ‘Round’, ‘Chantenay’ and ‘Imperator’. Some growers prefer to grow indoor round-shaped carrots.

Growing technologies

Soil preparation

Clean the soil in the greenhouse of previous crops and weeds. Spread organic fertilizers (e.g. compost, peat or decomposed manure) on the soil before tilling. Carrot responds well to applications of 6–10 kg of compost per greenhouse square metre. Soil preparation is fundamental when growing carrots in the greenhouse. If the soil is very compact, plough before preparing with a rotary harrow. The soil surface must be well levelled to ensure uniform depth of sowing. Carrots grow very well in raised beds (Plate 8).

Seeds and planting

It is recommended to use graded seeds with a diameter > 0.8 mm for indoor planted carrots. Carrots are normally sown straight in the ground and then thinned in stages to obtain the correct spacing. The timing of seeding depends on the type of indoor construction and the planned harvest time. In order to harvest carrots at the beginning of April, it is recommended to sow seeds in December. Similarly, for a harvest at the end of April, seeds need to be sown in January. To harvest carrots in May, sowing is carried out in February. The seeding rate is 1.0–1.2 g m^{-2} at a depth of 1.0–1.5 cm. For a good yield, rows are 12–14 cm apart, with 3–4 cm between plants within rows (5 cm for larger carrots). Seeds can be mixed with sand to facilitate sowing. Some growers mix radish seeds with carrot seeds. Carrot seeds are slow to germinate, while the radish – which germinates and grows very quickly – marks the row until the carrots come up. When the carrot seeds germinate and plant emergence reaches 50%, pull out the radish seedlings. When the plants reach a height of 4 cm, they are thinly spaced to 5–6 cm between plants. Plant density should be 60–80 plants m^{-2}.

Plant care

At emergence of seedlings, irrigation is kept at a minimum. Soil moisture should be constant, especially in the phase of root development, so as to prevent cracking caused by dry conditions. Soluble NPK fertilizers (ratio 1 : 2 : 2) are applied with irrigation at a rate of 1–2 g $litre^{-1}$ of water. Too much nitrogen causes excessive top growth. Since carrots are root crops, the greatest impact on produce quality comes from soil-inhabiting pests (e.g. wireworms, cutworms and vegetable weevils). Other pests (e.g. carrot weevil, carrot rust fly, willow-carrot aphid) affect carrot plants grown in greenhouse. Various pest control approaches – cultural practices (irrigating,

FORIGO

Plate 8
Making raised beds in a greenhouse

weed control, seed and soil preparation) and biological or chemical control – are adopted to limit yield losses. In the case of greenhouse carrot crops, powdery mildew can cause significant damage. This disease occurs in greenhouses with high humidity, a condition favourable for infection. To prevent infection, always ventilate the greenhouse after irrigation.[3]

Harvesting

Indoor carrots are generally ready for harvest after 2.5–3 months, when the root diameter is 1.3 cm and the carrots are succulent with a good colour. Greenhouse carrots are harvested manually: dig gently to expose the top of the root and gently, but firmly, pull the root from the soil. Some growers select only carrots of marketable size and make 2–3 selective harvests. Greenhouse carrots are tied in bunches of 5–10 plants and packed in plastic and wood crates. Yield is about 50–65 bunches per square metre of greenhouse.

ONION

Introduction

Onion (*Allium cepa* L.) belongs to the Alliacae family, which includes perennial and biennial herbaceous plants with well-developed or undeveloped bulbs. The whole plant – both above-ground parts (spring onions) and mature bulbs – are used for consumption. The dry matter content of spring onion is around 12%, of which the majority are simple sugars (80–90%). Spring onion is high in potassium, calcium, magnesium and iron (Gvozdanovic-Varga *et al.*, 2013). Green leaves contain vitamin C and pigments that are antioxidants. The characteristic odour comes from essential oils, which are antimicrobial and the reason for onion's well-known healing properties. The growing period is short, the temperature and light requirements modest, making this species suitable for autumn–winter and early spring production.

Environmental requirements

Onion requires modest temperatures, moist soil throughout the growing season and 70–80% air humidity; it is therefore a suitable preceding crop, cover crop or intercrop in the greenhouse. Temperature requirements are as follows:

- Optimum soil temperature for germination and emergence: 20 °C (≥ 2–3 °C)
- Optimum soil temperature for root formation: 10 °C
- Optimum air temperature for leaf growth: 18–20 °C

The optimum soil temperature for sprouting and emergence is 18–20 °C during the day and 12–15 °C at night. The length of individual growth phases depends mainly on the temperature. At 5–8 °C, sprouting lasts 25–35 days; at 18–20 °C, it

[3] See Part II, Chapter 5.

TABLE 1
Conditions and systems of spring onion farming in the greenhouses

Production time[a]	Planting date	Object type	Production duration (weeks)	Number of plants m^{-2}	Yield (kg m^{-2})
PS	Oct. – Nov. Mar. – April	Cold agrotextile	4	180–200	4–5
PS, mixed crop, lettuce and onion	Dec. – Jan.	Heating agrotextile	3	60–80	1.5–2
PS	Feb.	Heating	4–5	220–250	4–5

[a] PS = Planting of onion sets.

lasts 10–12 days; and at 20–25 °C, just 3–5 days. Once the onions sprout, maintain the greenhouse temperature at 8–10 °C to allow the roots to develop; temperatures > 20 °C slow the growth. The optimum temperature for foliage growth is 18–20 °C, while temperatures > 25 °C cause excessive foliage growth, elongation and deformity of leaves. Relative humidity in the greenhouse should be 50–60%. Spring onion does not require additional lighting.

Soil requirements

Onion requires fertile and structured soils with good physical and chemical properties and a pH of 6.8–7.5; it will not grow on acid soils.

Growing cycles

In the agro-ecological conditions of SEE countries, spring onion is produced in greenhouses from onion sets (varying in sizes) and transplants. For early planting, onion sets of about 25 mm diameter, or even larger size bulbs, should be used. Transplants grow in late August and are planted in greenhouses in October.

Spring onion farmers use domestic varieties produced from onion sets, i.e. bulbs that are not of standard quality (Cervenski *et al.*, 2013). Onion bulbs of domesticated varieties come in a wide range of shapes and colours (Plate 9), including 'Stuttgarter Riesen' and 'Bianca di Maggio' varieties. Transplants are produced from winter white bulb onion varieties. Winter white bulb onion varieties, such as Silverskin, are grown from transplants.

Plate 9
Onion sets of different colours and sizes for planting


GVOZDANOVIC-VARGA

Plate 10
Successive planting


GVOZDANOVIC-VARGA

Plate 11
Spring onion grown from sets of different sizes

Growing technologies

Soil preparation

Prior to tillage, remove all plant residues and apply organic fertilizers or manure. Perform basic tillage at a depth of 20–25 cm, and prepare the seed bed by crumbling soil at a depth of 8–10 cm, i.e. the optimum sowing depth.

Planting

Spring onions are suitable for successive planting, every 15 or 20 days, prolonging the harvest period. When sets are planted from October to late February, spring onion matures in 30–40 days (depending on the variety and greenhouse environmental conditions). Planting is done in bands of 4 or 5 rows at the following distances: inter-row 20 cm, intra-row 2–3 cm and inter-band 40–50 cm.

Irrigation

After planting and crop emergence, it is important to irrigate well; during crop growth, decrease the irrigation rate. Spring onions require irrigating at regular intervals during crop growth through to transplanting, after which fewer irrigations are required.

Fertilization

Take soil samples at least once per season for agrochemical analysis to understand the specific nutrient requirements. During tilling, incorporate only organic fertilizers (e.g. aged manure or NPK in the ratio 2 : 1 : 3). If necessary, apply a foliar top-dressing with addition of adhesives.

Pests and diseases

The main conditions for successful spring onion farming are use of good healthy planting material and maintenance of high standards of greenhouse hygiene. Due to the short growing period, there are almost no pest and disease problems (Table 3).

Harvest

High-quality spring onion has 6–9 leaves and a long white pseudo stem; it matures 20–45 days after planting, depending on the variety, set size, harvest date and cultivation system. Spring onions yield 1.5–5.5 kg m^{-2}.

GARLIC

Introduction

Garlic (*Allium sativum* L.) belongs to the Alliacae family. The use and cultivation of garlic dates back to the ancient civilizations, thanks to its high biological value, and nutritive and healing qualities. It has a high content of dry matter (35–40%), protein (5–6%) and sugar (22–25%). Of the complex sugars, garlic contains inulin-type fructose polymers (17.4%) (Muir *et al*. 2007) and is safe for diabetics. The foliage of young plants contains vitamin C and minerals. The main ingredients of garlic's essential oils are sulphur compounds, which have antimicrobial effects.

Environmental requirements

Garlic requires a moderate temperature and is resistant to low temperatures and frost. Sprouting begins at 3–5 °C; the optimum temperature for root formation is 10 °C, while it is 16–18 °C for above-ground parts. During the growth period, relative humidity should be 50–60%. The foliage forms during short days; therefore, spring garlic is grown in autumn and winter when days last 10–12 hours.

Growing cycles

Planting begins in early September and lasts until the end of November (Table 2). The later garlic is planted, the longer the vegetation period. Garlic planted in the early period is ready after 40–50 days, compared with garlic planted later (ready after ≤ 60 days). In tunnel greenhouses, garlic sprouts after 10–12 days. In the early stages of development, lower temperatures are required for rooting and sprouting. Optimal temperature is essential for leaf growth in later stages. Garlic contains carotene, and the whole plant is rich in K, Fe, Zn and carbohydrates, while having low energy value. It also contains alliin that has antimicrobial effects.

TABLE 2
Required quantity of cloves depending on size and cultivation system

Planting date	Planting distance	Number of plants	Quantity of cloves (g m^{-2})		
	(cm)	(per m^2)	3 g	4 g	5 g
Sept. – Oct.	50+25+25+25+25+25+25+50	150	450	600	750
	50+25+25+25+25+25+50	125	375	500	625
	50+30+30+30+30+50	100	300	400	500

Plate 12
Selection of cloves for planting

Variety selection

Winter garlic and flowering garlic with a shorter growing cycle are used for spring garlic cultivation. Domestic garlic varieties and domesticated populations produce the best results.

Growing technologies

Planting begins in late September and lasts until December (successive planting every 7–10 days). Planting cloves are classified by size (Plate 12). Plant cloves in 4–6-row bands at the following distances: inter-row 25–30 cm, intra-row 4 cm (Table 2). With early planting, the intra-row distance can 2–3 cm. Plant pointed cloves end up with the tip 3 cm beneath the surface. Planting at a greater depth leads to delays in sprouting; if planting is shallow, the cloves protrude from the soil due to intensive root growth and the plant withers.

Irrigation

Water deficit at the root formation stage adversely affects initial plant development. Irrigation is necessary after planting, with enough water to wet the soil to a depth of about 10 cm. After sprouting, adjust the irrigation rate according to the greenhouse air temperature and plant development stage.

Fertilization

Garlic prefers very fertile soils and abundant fertilization with easily available nutrients is required. Prepare the greenhouse (low and high tunnels, plastic greenhouses) by applying appropriate quantities of manure (2–4 kg m^{-2}) and NPK (ratio 2 : 1 : 3) fertilizers (10–15 g m^{-2}). Apply foliar top-dressing of nitrogen or liquid fertilizer complex as the first foliage appears.

GVOZDANOVIC-VARGA

Plate 13
Spring garlic plants grown from cloves of various sizes

Pests and diseases

The basic crop management measure is to plant good healthy cloves. Use of chemicals is limited due to the short growing period (Table 3).

Harvest

Harvesting of garlic takes place selectively, when plants have 3–4 leaves, 40–60 days after planting. Tie in bundles of 3–5 plants. The highest yields are achieved when the crop has formed 5–7 leaves (Plate 13).

WELSH ONION

Introduction

Welsh onion (*Allium fistulosum* L.) is a perennial species used for growing spring onions. It does not develop bulbs, but has pseudo-bulbs with a characteristic elongated and thickened stem and very lush foliage. Leaves are rich in vitamin C and beta-carotene, and the whole plant is rich in K, Fe, Zn and carbohydrates while having low energy value. Welsh onion also contains alliin, which has antimicrobial effects.

Environmental requirements

Welsh onion requires modest growing conditions; it sprouts at 2–3 °C, but the optimum temperature is 18–20 °C. During the growing period, maintain the greenhouse temperature at 15–20 °C during the day and 5–10 °C at night.

Growing cycles

Welsh onion is sown directly from seeds in September and is ready for harvest in November (60–70 days). Growing for transplant production begins in late September, as the crop matures for harvest in December (60–65 days after transplanting).

Variety selection

Use seeds of commercially available varieties (e.g. 'Savel', 'Parade').

Growing technologies

Welsh onion has good tolerance to low temperatures and lack of soil moisture (drought), thanks to its well-developed root system, which is 2–3 times larger than that of onion. It may be grown by direct seeding or from transplants in tunnel greenhouses without additional heating. Direct sowing starts in early

September with 4–8 g m^{-2} of seed sown in 4–6-row bands and then covered with compost. Inter-row spacing is 15–20 cm; after thinning, leave 2–3 cm of intra-row spacing. Carry out the first thinning when plants have 2–3 leaves.


TODOROVIC

Plate 14
Production of Welsh onion in a high tunnel greenhouse

Irrigation

Maintain optimal soil moisture after sowing and during sprouting. After thinning, irrigation rates depend on the temperature and crop growing stage.

Fertilization

The crop benefits greatly from organic fertilizers (aged manure or compost), grows fast and has lush foliage. Carry out agrochemical analysis of soil and organic fertilizers prior to planting. In seedling production, NPK fertilization (ratio 2 : 1 : 3) is necessary during the intensive phase of growth of the above-ground part of the plant (Plate 14).

Harvest

Spring onion, grown from Welsh onion, is harvested from November to January. Plants should have 4–6 formed leaves, pseudo-stem diameter of 0.6–1 cm and length of 7–10 cm. Tie in bundles of 5–7 plants. Yield reaches 4–8 kg m^{-2}.

GAP recommendations – Root and onion crops production

- When introducing a new crop (root and onion crops) in the production system, gather information on the technological aspects and carry out trials before planting commercial volumes.
- Use domestically registered varieties of short growing season (root vegetables) and local populations (onion and garlic).
- For greenhouse production use only high-quality seeds, treated for pests and diseases.
- Take care to prepare the soil well: it must not be compacted and it requires a high level of organic matter.
- Remember: indoor plants thrive, but pests and diseases are more aggressive indoors than outdoors.

For new crops: gather information, perform trials BEFORE cultivating on a commercial scale!

TABLE 3
Identification and control of the most common root and bulb vegetable disorders, pests and diseases

Symptoms	Reasons	Prevention and control measures
Radish		
Chlorotic angular lesions on leaves slowly turning into necrotic patches Greyish fluffy growth on undersides of leaves	Downy mildew – *Peronospora parasitica*	Disinfect soil using steam Apply balanced N fertilization Adopt irrigation methods that do not wet leaves
Shoot wilting Vascular necrosis	Fusarium wilt – *Fusarium oxysporum*	Use resistant cultivars/hybrids Adopt hygiene and sanitary measures Apply balanced fertilization
White pustules on cotyledons and true leaves	White rust – *Albugo candida*	Remove plant debris and weeds Apply balanced fertilization
Small black–red areas on roots, expanding and merging Roots constricted at sites of lesions	Black root – *Aphanomyces raphari*	Use resistant cultivars/hybrids Remove plant debris and weeds Apply optimal irrigation and fertilization
Brown–yellow circular lesions on root, irregular, merging Cracking of affected tissue	Common scab – *Streptomyces scabies*	Adopt crop rotation Avoid soils with increased pH Use resistant cultivars/hybrids Apply optimal irrigation
Small rounded holes in the foliage Presence of numerous small black beetles Withering and drying of damaged foliage with sieve-like appearance	Flea beetle – *Phyllotreta* spp.	Eradicate weed brassicas Adopt quality tillage Apply adequate irrigation Install insect netting cover Use pheromone traps
Leaves turning yellow, drying up Appearance of honeydew White aphids on lower leaf surfaces, flying when disturbed	Greenhouse whitefly – *Trialeurodes vaporariorum*	Adopt hygiene and sanitary measures Heat empty facility 5–8 days at 25 °C Eradicate weeds Apply optimal fertilization and irrigation
Plant interior filled with tunnels and excrement	Cabbage stem weevil – *Ceuthorrhynchus quadridens*	Adopt quality tillage Install insect netting cover Install ventilation systems

TABLE 3 (cont'd)
Identification and control of the most common root and bulb vegetable disorders, pests and diseases

Symptoms	Reasons	Prevention and control measures
Carrot		
White fluffy mycelial growth on leaves Severe infection of older leaves Plants exhausted by retro vegetation	Powdery mildew on carrot – *Erysiphe heraclei*	Adopt deep ploughing of crop residues Adopt crop rotation Use healthy seed Apply balanced fertilization
Light, watery lesions with soft tissue and rot Withering and wilting of leaves above infected plant parts Formation of white fluffy mycelia with dark spots (sclerotia) under moist conditions.	White mould – *Sclerotinia sclerotiorum*	Adopt deep tillage Disinfect soil or use sterile medium Use less susceptible cultivars Remove infected plants
Radicle and shoot decay and rot Oval dark yellow–black patches on developed leaves Dark, sunken patches on root neck leading to decay of whole plant	Black rot – *Alternaria radicina*	Use healthy and treated seed Adopt crop rotation Remove and eradicate infected plants
Bacterial soft rot on root Softening of tissue Leakage of liquid of unpleasant odour	Bacterial soft rot – *Pectobacterium carotovorum* subsp. *carotovorum*	Sow in well-aerated soils Apply optimal irrigation Apply balanced fertilization with N Avoid mechanical damage to roots
Deformed yellow or red leaves Presence of aphids on leaves Stunted growth and withering	Leaf aphids	Adopt quality tillage Install dense netting cover over ventilation system Eradicate weeds
Curling and withering of leaves Presence of insects in imago and larva stages	Carrot psyllid – *Trioza viridula*	Remove plant debris Adopt quality tillage Remove affected plants Use pheromone traps
Root tunnels of varying length filled with larvae excrement Unpleasant odour Susceptibility to rotting Purple leaves turning yellow and withering	Carrot fly – *Psila rosae*	Install ventilation Remove affected plants Eradicate weeds
Stunted, deformed and woody roots Beard-like appearance of lateral roots Stunted growth of plants Red–yellow spots on leaves Withering and wilting of older leaves	Carrot cyst nematode – *Heterodera carotae*	Eradicate weeds Adopt quality cultivation practices Apply balanced fertilization Apply optimal irrigation Apply fertilization with K to decrease abundance of cysts

TABLE 3 (cont'd)
Identification and control of the most common root and bulb vegetable disorders, pests and diseases

Symptoms	Reasons	Prevention and control measures
Onion vegetables		
Delays in development Leaves pale green Older leaves yellow and dry, starting at the top	N deficiency	Apply adequate fertilization
Reduced turgour of onions Tips of older leaves dying out, but leaves not yellow	K deficiency	Apply adequate fertilization and irrigation
Oval or elongated lesions of various sizes on foliage Greyish discoloration under high moisture conditions	Downy mildew on onions – *Peronospora destructor*	Use healthy seedlings Remove plant debris and eradicate wild plants Apply balanced N fertilization Install ventilation Adopt optimal plant density
Localized lesions on older leaves, initially yellow then dark brown and elongated Black growth in centre of lesions	Purple blotch – *Alternaria porri*	Use healthy seedlings Install ventilation Apply moderate irrigation Apply balanced fertilization
Stunted growth Foliage flattened, shrivelled, deformed Foliage yellow, dried up, straw-like Chlorosis with narrow streaks and stripes Chlorotic spots along leaf blades, wrinkled and curled	Iris yellow spot virus Onion yellow dwarf virus Garlic mosaic virus Leek yellow stripe virus	Use virus-free seedlings Remove infected plants Control virus vector pests Adopt measures benefiting plant growth and development
Stunted growth Spongy bulbs Foliage short and thick with light–dark brown patches	Nematodes	Use healthy seedlings Remove plant debris and weeds Plant marigolds (*Tagetes* spp.)
Foliage silvery and spotted Stem brown and dried off	Onion thrips – *Thrips tabaci*	Eradicate weeds regularly Apply balanced fertilization with extra P and K Apply optimal irrigation Remove plant debris
Outer layers yellow and dried up (onion) Stem soft and shrivelled Larvae on cracked tunica	Allium leafminer – *Napomyza gymnostoma*	Adopt quality tillage Remove individual infected plants Remove wrapping leaves with pupae Install insect netting cover
Foliage yellow, withered, dried off Pseudo stem and bulb soft to touch Plant easily picked from soil Larvae in central part of pseudo stem and bulb	Onion maggot – *Hylemyia antiqua*	Remove affected plants Install ventilation Install insect netting Adopt intercropping with carrot
Silvery-white stripes Larvae inside leaves and bulbs Plants dried off	Leek moth – *Acrolepiopsis assectella*	Adopt quality tillage Remove infected plants and weeds

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