TOPPLANT

Co-funded by the
Erasmus+ Programme
of the European Union

GUIDELINES FOR PLANT PROTECTION IN ORGANIC CULTIVATION OF ONIONS

DRAGAN ŽNIDARČIČ

MATE
MAGYAR AGRÁR- ÉS
ÉLETTUDOMÁNYI EGYETEM

BIOTEHNIŠKI
CENTER NAKLO

AGRONOMSKI FAKULTET ZAGREB
MCMXIX

ipCENTER
room for learning

biohelp

Guidelines for plant protection in organic onion production

1. Introduction

The onion (*Allium cepa* L.), also known as the bulb onion or common onion, is a vegetable that is cultivated species of the lily family (Liliaceae) and is the most widely cultivated species of the genus *Allium*. Nowadays, onions are used in variety of forms. They can be eaten in fresh, frozen, canned, pickled and dehydrated forms. Many reports have indicated that onions have a wide range of beneficial properties for human health, such as polyphenols, flavonoids, and antioxidants as well as carbohydrates and sugar.

Organic production of onion is a comprehensive system designed to increase the productivity and fitness of communities within the agroecosystem, including soil organisms, plants, livestock, and people. Organic onion growing accord with the three basic principles that reveal their essence:

- production package concentrates on building up of the biological fertility of the soil so that the crops nutrient removal and release are in synchrony;
- control of crop pests, diseases and weeds is achieved largely by the development of an ecological balance within the system and by the use of biopesticide and various cultural techniques such a crop rotation, mixed cropping, and cultivation practices;
- organic farmers recycle all organic wastes and manures generated within a farm.

Since onion is consumed as fresh vegetable, used in processing and pickling developing organic production protocols is highly relevant in the present context.

2. The phenological growth stages and BBCH-identification keys of bulb vegetables (after Feller et al. 1995)

Growth stage	Code	Description	Growth stage	Code	Description
0: Germination	00	Dry seed,1 dormant bulb[2]	**5: Inflorescence emergence**	51	Onion bulb begins to elongate
	01	Beginning of seed imbibition[1]		53	30% of the expected length of flower stem reached
	03	Seed imbibition complete[1]		55	Flower stem at full length; sheath closed
	05	Radicle emerged from seed.[1] Roots appearing[2]		57	Sheath burst open
	07	Cotyledon breaking through seed coat[1]		59	First flower petals visible; flowers still closed
	09	Emergence: cotyledon breaks through soil surface.[1] Green shoot visible[2]	**6: Flowering**	60	First flowering
		Cotyledon visible as hook[1]		61	Beginning of flowering: 10% of flowers open
		Hook stage: hooked cotyledon green[1]		62-64	20%/ 30 % / 40 % of flowers open
		Whip stage: cotyledon has whip-like form1		65	Full flowering: 50% of flowers open
1: Leaf development	10	Advanced whip stage: whip begins to die off[1]		67	Flowering finishing: 70% of petals fallen or dry
	11	First leaf (> 3 cm) clearly visible		69	End of flowering
	12	2nd leaf (> 3 cm) clearly visible	**7: Development of fruit**	71	First capsules formed
	13	3rd leaf (> 3 cm)		72-78	20% to 80 % of capsules formed
	14	Stages continuous till . . .		79	Capsule development complete; seeds light
	19	9 or more leaves clearly visible	**8: Ripening of fruit and seed**	81	Beginning of ripening: 10% of capsules ripe
4: Development of harvestable vegetative plant parts	41	Leaf bases begin to thicken or extend		85	First capsules bursting
	43	30% of the expected bulb or shaft diameter reached		89	Fully ripe: seeds black and hard
	45	50% of the expected bulb or shaft diameter reached	**9: Senescence**	92	Leaves and shoots beginning to discolour
	47	Bolting begins; in 10% of the plants leaves bent over[3] 70% of the expected shaft length and diameter reached[4]		95	50% of leaves yellow or dead
	48	Leaves bent over in 50% of plants[3]		97	Plants or above ground parts dead
	49	Leaves dead, bulb top dry; dormancy[3] Growth complete; length and stem diameter typical for variety reached[4]		99	Harvested product (seeds)

[1] Seed sown, [2] Onion sets, [3] For onions, garlic; [4] For leek

3. Agronomic practices

Preparation for planting onions	Site selection	Minimizing potential production problems is essential to all farming operations. This is especially true for organic producers. One of the most effective means of reducing potential problems is through proper field site selection. Onion grows in mild climate without extremes of high and low temperature. The onion is cool season crop; it is tolerant to frost in the young stage. However, it is sensitive to heat. Plants at early stage can withstand the freezing temperature. Beside temperatures, three points should be considered when selecting a field to produce vegetables: field topography, soil type, and water availability and quality: - Topography refers to the physical characteristics of the overall field site and includes such conditions as; contour, soil depth, water and air drainage, and, the presence of rock. Poorly drained fields or those with low areas can become water logged during periods of excessive rain. Such conditions can enhance the incidence of diseases, reduce plant vigor and yield. Sites with slopes of 1.5 % or more should be avoided to prevent excessive erosion problems; - In organic production, soil health is essential. Soil quality influences its ability to provide an optimum media for growth, sustain crop productivity, maintain environmental quality, and, provide for plant health; - Onion crops generally require more total water and more frequent irrigation than most other agronomic crops. Therefore, only fields that have easy access to an abundant water source should be considered for onion production; - Water quality is as important as water quantity when selecting a water source for a field. Water source for onion irrigation should contain less than 400 ppm soluble salts. Therefore, avoid water sources containing high levels of toxic elements such as sodium, boron or aluminum. A four-year crop rotation is suggested.
	Soil	- Onions can be grown on all types of soil such as sandy loam, silt loam and heavy clay soils. However, deep friable, highly fertile sandy loam to clay soil rich in humus is considered as ideal. - Sandy soil needs frequent irrigation and favours early maturity. Whereas heavy soils restrict the development of bulbs and the crop matures late as compared to light soils. - The onion plant is sensitive to high acidity and produces maximum yields over a fairly narrow range of soil reaction (pH range between 5.8-6.5 is considered as optimum). Good yields are produced on muck soils over a wider range of soil reaction than on mineral soils. - Good drainage is essential, as water-logging results in total failure of the crop. - Ideal soil: organic in nature, rich in nitrogen, and have a high water-holding capacity.
	Selection of varieties	Variety choice is an important component of organic crop management. Today in EU is available a very large number of varieties and forms of onion: - 'Red Baron' (red colour and a strong flavour; resistant on Pink Root Rot *Phoma terrestris*). - 'Red Long of Florence' (the onions taste mild and sweet; Disease resistance not specified). - 'Rijnsburger' (the onions have an excellent storage capacity). - ’Stuttgarter Riesen’ (a well-storable yellow onion, which can be used for the cultivation of scallions as well; resistant on downy mildew).

		- 'White Lisbon' (the leafage is light green and stands nicely upright; *Fusarium oxysporum* disease resistance not specified). - Welsh Onion 'Ishikura Long White' (onion that forms a long, white, thick shaft without forming a sphere; resistant to Pink Root Rot and botrytis leaf blight). - ’Valencian Onion’ (big round bulbs; resistant to *Thrips tabaci*). - 'Red Sturon' (an early maturing variety which shows good resistance to bolting; Disease resistance not specified). Note: If no certified organic seed source is available of the variety needed, the growers are allowed to use non-organically produced seed, but they must be untreated.
	Planting material	All reproductive material must conforms to organic standards.
	Plant spacing	- Onions should be spaced 5 to 10 cm apart, with 35 to 40 cm between rows. - Onion plant spacing is a function of our intended size — the closer together, the smaller the bulbs will be. If we're planting for a harvest of green onions, they can be as little as 5 cm apart. For normal "medium"-sized onions, 6 to 8 cm is appropriate; for extra-large varieties, 8 to 12 cm. - Onion seeds can be sown close together, and thinned out once the seedlings have grown.
	Soil preparation for planting	- Onions are relatively hardy, so planting can begin as soon as the soil is dried out and workable in spring. - The goal of soil preparation is to replenish vital minerals and nutrients, as well as break up and loosen any compacted soil. - Soil preparation can be done at any time that the ground is not too wet or frozen. - Plants may be planted even when temperatures are quite cool. If a hard frost is expected, it is advisable to delay planting for a while until temperatures become more moderate. Generally, as long as the soil is workable, it is fine to plant. - The seed-bed should be well pulverized and have a smooth surface. - It is a common practice to drag or roll the land just prior to planting. This is especially important for muck soils. - First of all, make sure that soil is free of weeds and rocks.
Agrotechnical practices	Soil maintenance	- Onion are not drought-tolerant crops because of their short root system. The plants are not resistant to saturated water during tuber growth and development. The unfavourable growing environment can be manipulated with the application of mulch. Mulch prevents evapotranspiration, erosion, retains soil moisture, inhibits weed seed germination and buffering of soil temperature. - Sources of organic mulch include plant debris or other organic substances. Organic mulch type includes the straw mulch, corn stem mulch straw, hay, or leaves. - In addition, mulch contribute to a diverse rotation schedule, a critical consideration for onions, which should only be planted on a three-to four-year cycle. - Besides mulch, the application of organic amendments such as compost, vermicompost and other forms of organic matter has been commonly used to improve plant productivity. Vermicompost is the deterioration of the organic material by earthworms. The application of vermicompost improves soil quality, available plant nutrients, organic matter, plant growth, and crop yield.
	Fertilization	Organic farmers recycle all organic wastes and manures generated within a farm.

		Before using organic manure, we should want to check it by different ways. Avoid using fresh animal manure, which contains various pathogens that are harmful to onions. Kill pathogens present in compost and apply manure at the best time to avoid excessive leaching and runoff. 6 tons/ha poultry litter are recommended, which should be pre-plant applied and incorporated prior to final bed preparation. Commercial organic fertilizers will also have to be pre-plant applied (e.g. Organic fertilizer Big plant; Bio Plantella Nutrivit Univerzal, Plantella Organic …). It is good to know that organic fertilizer should be applied at a rate at least 50 percent higher than the N-P-K percentages would indicate.
	Increasing biodiversity	There are many agricultural practices that onion farmers use to promote biodiversity: - conservation tillage minimizes soil disturbance by using tools that turn over the soil lightly or, in some cases, hardly at all. The practice can leave some crop residue on the soil's surface to lessen the opportunity for the soil to erode; - cover crops (under-sowing of green manures), are those planted by farmers in between the harvest of one main crop and the planting of another. These crops, such as rye, radishes kale, oilseed rape, vetches and stubble turnip, can assist with soil conservation, keeping soil from eroding and returning nutrients and benefits to the soil for future crops. In addition to their direct benefit for cultivating seasonal harvests, cover crops also provide habitat for birds and insects, another important component of biodiversity; - buffer strips; wide strips of land left or created between farming fields that help ease soil erosion and prevent water runoff. Often comprised of grasses, flowers and other native plants, these strips of land also promote biodiversity by providing a habitat for birds and other animals; - incorporation of organic matter; increasing organic matter provides shelter for soil microbes and intensifies soil biological activity, helping to lessen the risk of plant diseases. The breakdown of organic matter by soil microbes returns nutrients to the soil removed during crop production. Animal manures, cover crops, crop residues and organic amendments can be incorporated into the soil to increase organic matter content over time.
	Irrigation	- Onions are extremely sensitive to water stress. Regardless of the type of irrigation system used, both yield and quality can suffer if irrigation is delayed and available soil moisture is allowed to drop too low. - The crops require 350 to 550 mm of water throughout the growth cycle. It is recommended to give frequent, light irrigations which are timed when about 25% of available water in the top 30 cm of soil is depleted. Irrigation intervals of 2-4 days are a common practice. Excessive irrigation sometimes leads to the occurrence of diseases such as mildew and white rot. The root system is normally limited to the top 3 cm and roots rarely penetrate deeper (15 cm). - The first irrigation is necessary immediately after transplanting. - Irrigation should be stopped 15 to 20 days before uprooting the bulb or before the beginning of maturity. - Irrigation should be applied at 10 to 15 day intervals in cool weather and at one week intervals during hot weather. - Bulb formation and bulb enlargement (70 to 100 days after transplanting) are the critical stages for water requirement. - Generally, irrigation ig given 10 to 12 times. - Stop irrigation when the tops mature and start to fall off.
	Weed management	Because perennial weeds are very difficult to control in *Allium* crops, they have to be controlled in the preceding crop. The main methods of weed control are mechanical and thermal. Mechanical control includes harrowing and hoeing, while thermal

		control involves flame weeding to control small seedling weeds. The success of these methods depends on timing, on weather and soil conditions, and on the composition and density of the weed population. Crop rotation is important for disease control, but weed infestation can become a problem when onions follow crops such as potatoes, cereals and oil-seed rape.

4. Methods and tools to manage pests

Onion fly		The phenological growth stages and BBCH-identification keys of of bulb vegetables (after Feller et al. 1995)											
		00	09	11	13	14	19	41	43	45	47	48	49	50-99
Delia antiqua	**Damaging stage of the insect**	The onion fly is a major pest of onion. The onion maggot is the larva of a small fly resembling the housefly, but smaller. In northern temperature regions, onion fly undergoes three generations annually in the growing season and overwinters as pupae in the soil, emerging in spring, typically in early- to mid-May. Of the three generations, the first tends to be the most damaging because feeding on seedling onions results in high plant mortality. Damage done by first generation larvae on seedling onions is usually clustered in the field, as a result of clustered oviposition and larval movement to adjacent undamaged plants.												
	Symptoms			The larvae penetrate the host through the base of the leaf shoots or roots, and feed on the decomposing tissue. Early symptoms of *D. antiqua* presence show as yellowing and wilting of the host's central leaves. Green and apparently healthy leaves will become flaccid, and the whole plant may collapse. Later generations of larvae tunnel into the onion bulbs. Bulbs will be deformed and susceptible to storage rots after harvest. The 1st instar larva is very harmful because it attacks mainly on new host seedlings and it is a threat to agro ecosystem. Due to the voracious attack of 1st instar larva, the attacked plant dies before the larvae complete its development stage and then attack the new The 2nd and 3rd instar larva do not kill plants, but the damaged onion bulbs are not marketable.										
	Conditions for the pest appearance	Optimum conditions for egg development are temperatures of 17-22 °C and humidity levels at 75-80 %. Adult activity tends to decline with the increase in temperatures and oviposition ceases at temperatures exceeding 30 °C. Lowered temperatures stimulate some of spring generation pupae to enter winter diapause. Onion fields surrounded by a greater proportion of forest or wooded habitat may be at higher risk for *D. antiqua* infestation. Lower temperatures and increased soil moisture are associated with increased onion fly damage. Onion fly larvae perform better in "lighter" soils, i.e. soils with more organic matter compared to clay-rich soils. *D. antiqua* flies display an edge-effect adjacent to onion field edges bordered by wooded areas, in contrast to those bordered by other vegetable crops.												

	Prognostic models to be used	The flight of imagos of spring generation occurs in April - May during cherry and dandelion flowering. Flies of the second generation appear at the end of June and the beginning of July. Females need additional feeding on nectar of flowers for egg laying. Optimum conditions for egg development are temperatures of 17-22 °C and humidity levels of 75-80 %. Lowered temperatures stimulate some of spring generation pupae to enter winter diapause. Cumulative growing degree days (GDD) can be used to monitor the activity of onion fly: Peak flight GDD (°C) 1 st generation 390 2 nd generation 940 3 rd generation 1635 Adult flies may be monitored with blue and yellow sticky traps.
	Control strategies	**Prevention:** - Crop rotation can considerably reduce damage by *D. antiqua*. However, when rotated fields are near (< 500 m) overwintering sites, crop rotation does not reduce maggot damage to below economically damaging levels relative to non-rotated controls. - Crop sanitation including the removal and proper disposal of cull and volunteer onions, and avoiding damaging bulbs in the field is an important facet of *D. antiqua* management. - Delayed planting creates asynchrony between the crop and the first generation of the pest, thus allowing the crop to escape the pest in time since *D. antiqua* flies preferentially oviposit on larger onions. - In the absence of onion breeding lines with traits that confer resistant qualities to onion fly, there are no commercially available resistant cultivars. - Because *D. antiqua* oviposits on or at the base of onion plants, the use of physical barriers to exclude flies has been considered; row covers effectively reduce infestations of both *D. antiqua* and *D. radicum*. Non-woven fibers applied to the soil surface forming a web-like barrier are effective at reducing oviposition by *D. antiqua*; however, the installation of a physical barrier is not practical for large-scale onion production and should only be considered in small-scale management applications. **Biological control**: Predators of *Delia* spp. include many (60-100) species of staphylinid and carabid ground beetles, generalists that feed on eggs and early instars. Some staphylinid beetles, including *Aleochara bilineata* and *A. bipustulata*, parasitize *Delia* pupae in addition to feeding on eggs. The braconid fly *Aphaereta pallipes*, which has a broad host range, also parasitizes *D. antiqua* successfully. In addition to predators and parasitoids, other biocontrol agents of *Delia* include entomopathogenic fungi (EPFs) and nematodes (EPNs). **Compounds with proven activity**: Azadirachtin, *Bacillus thuringiensis* ssp. *Aizawai.*

Onion thrips			The phenological growth stages and BBCH-identification keys of of bulb vegetables (after Feller et al. 1995)												
			00	09	11	13	14	19	41	43	45	47	48	49	50-99
Thrips tabaci	Damaging stage of the insect		Both adult and larval thrips feed within the mesophyll layer using a punch-and-suck motion. They are feeding on onion leaves, bulbs and flowers. A complete generation requires 3-4 weeks during the summer months. Five to eight generations may occur each year.												
	Symptoms	Whole plant					Thrips prefer to feed on the newly emerged leaves in the centre of onion necks. Removal of chlorophyll causes the feeding area to appear white to silvery in colour. Thrips feeding can stunt plant growth and cause damaged leaves to become papery and distorted, develop tiny pale spots (stippling), and drop prematurely. Infested terminals may discolour and become rolled. Water loss through the damaged leaf surface may cause stress and reduced plant growth. Fast plant maturity due to thrips injury may shorten the bulb growth period. Following harvest and during storage, thrips may continue to feed on onion bulbs, causing scars that reduce quality and visual appearance of bulbs.								
	Conditions for the pest appearance		Hot and dry weather can lead to an increase in onion thrips populations and the severity of thrips injury to onion. Heavy rains have been shown to wash onion thrips from plants. Additionally, water stress may impact the nutritional quality of onion plants and also increases the attractiveness of the plants to thrips.												
	Prognostic models to be used		**Visual inspection:** thrips sampling is important to optimize management strategies and to inform the grower about thrips population pressure over time. Sampling should begin when plants have at least 4-5 leaves or by mid-June. An effective sampling method for pest management decisions is in situ counts – open the neck of onion plants and quickly count thrips adults and larvae before they disperse or hide. The majority of thrips will be at the base of youngest leaves in the lower center of the neck. Rueda and Shelton (1995) recommend at an action threshold of 5 thrips per plant.												

	Control strategies	**Prevention**: - Field location: Avoid planting onions adjacent to grain and alfalfa fields. Small grains and alfalfa are common rotational crops for onions, so it may be difficult to implement this recommendation. Plant younger fields upwind, relative to prevailing winds, from older fields. This applies to fields planted with transplants as well. - Seedling transplants: Inspect onion transplants for thrips infestation, and discard infested transplants. - Nitrogen management: Fertilize onions with adequate, but not excessive amounts of nitrogen. Deliver nitrogen in multiple applications throughout the onion growth period. - Mulches: Straw or other mulch placed on the plant bed has been shown to reduce thrips populations and improve onion growth. - Pre-planting and post-harvest sanitation: Remove or destroy volunteer onion plants and debris. - Row covers, hot caps, and other types of cages with a fine mesh can exclude thrips from onions. Apply row covers before crops emerge or to pest-free plants during planting. Plants are normally covered or caged only while they are young and most susceptible to damage. Once plants become larger or temperatures get warmer, remove covers to provide enough growing space and to prevent overheating. Drip or furrow irrigation is generally necessary when using row covers. **Biotechnical control**: - Trap crops and inter-cropping: other crops that are highly attractive to onion thrips include carrot, crucifers, cucurbits, and some flowers. Using a trap crop involves planting small strips or patches of the alternative crop within an onion field to attract thrips. The trap crop is disked under when thrips populations increase. Inter-cropping, or mixed planting, of carrots and onions has been shown to reduce onion thrips populations on onions by attracting them to the carrots. Thrips injury to carrots is not as economically damaging as injury to onions. In this case, both crops can be harvested. - Sprinkler irrigation: Overhead sprinkler irrigation has been shown to reduce thrips populations on onion plants. The physical action of water washing thrips from plants and water droplets standing on leaf surfaces are inhibitory to thrips. - Hanging bright yellow sticky traps. **Biological control**: Predators of onion thrips can be numerous, but are not usually in abundance until late summer, after the majority of thrips feeding injury has occurred. In onion fields without applications of toxic insecticides and with enhanced cultural practices (e.g., mulches, high organic matter, trap crops, inter-cropping), adequate densities of predators may be present to provide effective suppression of thrips during the summer. The primary predators that feed on thrips in onions include the black hunter thrips (*Aeolothrips* sp.), big-eyed bug (*Geocoris* spp.), minute pirate bug (*Orius* spp.), and green lacewing (*Chrysoperla* spp.) larvae. **Compounds with proven activity:** Azadirachtin, spinosad, natural pyrethrum - please check the registration for your country.

<table>
<tr><td colspan="3" rowspan="2">Onion leaf miner</td><td colspan="13">The phenological growth stages and BBCH-identification keys of of bulb vegetables (after Feller et al. 1995)</td></tr>
<tr><td>00</td><td>09</td><td>11</td><td>13</td><td>14</td><td>19</td><td>41</td><td>43</td><td>45</td><td>47</td><td>48</td><td>49</td><td>50-99</td></tr>
<tr><td rowspan="4">Phytomyza gymnostoma</td><td colspan="2">Damaging stage of the insect</td><td colspan="13">The onion leaf miner is a true fly in the Agromyzidae family and the damaging stage is larva that bore into the bulbs, stems, and foliage. In northern temperature regions, it undergoes three generations annually in the growing season and overwinters as pupae in the soil, emerging in spring, typically in April to mid-May.</td></tr>
<tr><td>Symptoms</td><td>Whole plant</td><td></td><td></td><td></td><td></td><td colspan="9">Adult females make repeated punctures in leaf tissue with their ovipositor. These punctures may be the first sign of damage. Larvae mine leaves and move towards and into bulbs and leaf sheathes. The damage they cause manifests as tunnels that look like erratic lines on the leaves as they travel to feed. In addition to the direct damage they cause, these feeding tunnels can be colonized by fungi or bacteria, such as those that cause soft rot. These secondary infections can cause the plants to rot and die off.</td></tr>
<tr><td colspan="2">Conditions for the pest appearance</td><td colspan="13">Spring emergence can be best detected by scouting wild alliums as opposed to emergence cages, and modelled using 350 degree-days above a lower threshold of 1.0°C. Spring adult flight occurs over five weeks. Larval development requires 22 and 20 d at 17.5 and 25°C, respectively.</td></tr>
<tr><td colspan="2">Prognostic models to be used</td><td colspan="13">Visual inspections: Finding adults is easiest in the cool temperatures of early morning and looking at the tops of the leaves. Finding the feeding scars on leaves is often easier than finding adults. One should also look for leaves that are curly, wavy, and distorted – although this typically happens later in the season, after the larvae have had a chance to do extensive damage. The other leaf miners that attack Alliums do not cause this symptom. Later in the growing season, we can pull plants that are exhibiting symptoms out of the ground and pull the leaves back to check for pupae.
Use of the baits: Yellow sticky traps are often used to identify the presence of leaf miners. The traps should be placed in late winter or early spring and checked regularly to identify which pests are visiting the onion crop. We can keep them in place throughout the growing season or replace in late summer to monitor the presence of the second generation.
Forecasting based on meteorological conditions:
Determine the intensity of onion leaf miner attacks using the following formula:
$$I = \frac{\Sigma(nxv)}{NxZ} x 100\%$$
Description: I = Intensity of attack (%); n= Number of plants having the same scale category of bored leaves; v= Value of scale of each attack category; Z= The highest scaling value of attack; N= Number of plants or parts of plants observed
Scale values to estimate the intensity of crop damage caused by leaf miner attacks:</td></tr>
</table>

Scale values	Number of larval/leaf curve	Plant damage level (%)	Plant condition
0	no symptoms of an attack	0	healthy
1	1-6	0-20	moderately damaged
2	7-12	20-40	medium damaged
3	13-18	40-60	heavily damaged
4	19-24	60-80	very heavily damaged
5	>24	80-100	Nearly dead plant

Control strategies

Prevention:

- chose a site where no member of the *Allium* family has been grown for at least one year; a longer rotation is even better.
- covering plants in February, prior to the emergence of adults, and keeping plants covered during spring emergence, can be used to exclude the pest.
- avoiding the adult oviposition period by delaying planting
- covering of fall plantings during the 2nd generation flight can be effective.
- growing a mixture of tillage radish, mustards, and rapeseed as a cover crop before growing yellow onions significantly reduced the numbers of adults.
- thoroughly work fields previously planted with susceptible crops before planting onion.
- at the end of the growing season removal of all infected material. Do not compost infected materials, but bag and trash them;
- solarize the soil. Solarization will not only kill miners' pupae but will decrease soil pathogens and increase beneficial microbes that will benefit plant growth later.

Biological control:

The parasitic wasp *Diglyphus isaea* lays its eggs on the larvae of all leaf miners in the Agromyzid family and kills them. Technically, these types of wasps are known as parasitoids. This type of treatment works best if the wasps are released early in the season before the adult onion leaf miner populations build up. These parasitoids can dramatically lower the populations of leaf miners, but they will not provide total control.

Compounds with proven activity: Azadirachtin - please check the registration.

Picture 4.1. Larvae of the onion fly
(© https://www.shutterstock.com)

Picture 4.2. Adult and larva of *Thrips tabaci*
(© https://www.shutterstock.com)

Picture 4.3. Onion leaf miner larva
(© https://www.shutterstock.com)

5. Methods and tools to manage diseases

<table>
<tr><th colspan="3" rowspan="2">Downy mildew</th><th colspan="12">The phenological growth stages and BBCH-identification keys of bulb vegetables (after Feller et al. 1995)</th></tr>
<tr><th>00</th><th>09</th><th>11</th><th>13</th><th>14</th><th>19</th><th>41</th><th>43</th><th>45</th><th>47</th><th>49</th><th>50-99</th></tr>
<tr><td rowspan="4">Peronospora destructor</td><td rowspan="3">Symptoms</td><td>bulbs</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">The pathogen persists as mycelium systemically infecting onion bulbs, but is not known to be transmitted in onion seed. The bulb tissue typically becomes soft and watery, lacking the firm quality that typical healthy onions have. The outer portion of the bulb also appears wrinkled and may take on an amber hue.</td><td></td></tr>
<tr><td>leaves</td><td></td><td></td><td></td><td></td><td colspan="7">Necrotic spots begin as yellowing spots that eventually turn brown or black as the leaf tissue dies. Older and outer leaves often show symptoms earlier than younger leaves. Leaf tips shrivel as the pathogen moves inward toward the stalk of the plant itself. The symptoms begin as elongated, pale yellow lesions which progress into small patches of fungal colonies that are gray. As the disease continues to progress, secondary infection by other pathogens may occur, leading to purple or brown colored spores in the lesions on the leaves, which characterizes the downy mildew disease. Systemically infected plants are dwarfed and pale green.</td><td></td></tr>
<tr><td>stalks</td><td></td><td></td><td></td><td></td><td></td><td colspan="7">The stalks of onion plants can also be infected by P. destructor, with symptoms appearing as yellow or brown necrotic areas along the stalk itself. Although P. destructor usually does not kill the entire onion plant, the pathogen reduces the growth of the onion.</td></tr>
<tr><td colspan="2">Conditions for the infection</td><td colspan="12">The pathogen overwinters in leaf debris as mycelium, and in the soil as oospores for several years. Under moist conditions, the pathogen sporulates on the affected tissues and spreads to other plants. The optimal temperature for P. destructor spore germination is 10 °C, and less sporulation occurs as the temperature increases. Oospores may be produced at up to 27 °C., however, most spores grow when temperatures are cooler. The disease of downy mildew as a whole is most likely to grow on plants that are in cool and damp environments, however, the pathogen has different ways of utilizing environmental factors depending on the condition.</td></tr>
</table>

	Prognostic models to be used	Downy mildew has complex environmental requirements, needing both cool temperatures and high humidity. Spore production occurs at or above a relative humidity of 95 % in the canopy. Spore production declines at temperatures above 24 °C and may be suppressed completely if temperatures are sustained above 28 °C for more than four hours, or above 30 °C for more than two hours. Nightly rainfall can also suppress spore production. Spores are airborne. After landing on healthy plants, they require leaf wetness for infection to occur. The length of leaf wetness required is directly proportional to air temperature. The research mentioned above assumes that for air temperatures of 2 to 16 °C, only 2 to 3 hours of leaf wetness is necessary for infection, whereas infection requires 5 hours of leaf wetness at 16 to 20 °C. The time between infection and sporulation can range from 8 to 16 days, but spores produced during a given night can infect new plants the following morning, and up to 3 days later. Therefore, downy mildew can develop into a damaging epidemic very quickly under favorable conditions.
	Control strategies	**Prevention:** -rotation of *Allium* species with other plants that are not hosts of *P. destructor*. Space plants out when planting them and ensure that the soil has adequate drainage to avoid overwatering. - removing plant debris throughout the growing season and after harvest. - avoid cultivators entering the field when it is wet, as well as avoid injuring the plants as they are growing. - an additional control mechanism includes selective breeding for plants that are resistant to the pathogen. Qualities of resistant plants include small cells with thick cell walls, flat leaves with pronounced layers, and high cuticle wax content. -avoiding sprinkler irrigation, using bulbs and seeds that are disease free, aligning rows with normal wind patterns, and planting *Allium* species during times when *P. destructor* is least likely to infect plants. **Biological control**: Biological control strategies have not been developed for downy mildew. **Compounds with proven activity**: Copper fungicides

<table>
<tr><th colspan="3" rowspan="2">Purple blotch</th><th colspan="12">The phenological growth stages and BBCH-identification keys of bulb vegetables (after Feller et al. 1995)</th></tr>
<tr><th>00</th><th>09</th><th>11</th><th>13</th><th>14</th><th>19</th><th>41</th><th>43</th><th>45</th><th>47</th><th>49</th><th>50-99</th></tr>
<tr><td rowspan="3">Alternaria porri</td><td rowspan="3">Symptoms</td><td>leaves</td><td></td><td></td><td colspan="8">The fungal spores germinate on onion leaves and produce a small, water-soaked spot that turns brown. The elliptical lesion enlarges, becomes zonate (target spot) and purplish. The margin may be reddish to purple and surrounded by a yellow zone. During moist weather, the surface of the lesion may be covered by brown to black masses of fungal spores.
Lesions may merge or become so numerous that they kill the leaf. Leaves become yellow then brown and wilt 2 to 4 weeks after initial infection. The lesion borders are reddish and surrounded by a yellow “halo.”</td><td></td><td></td></tr>
<tr><td>stem</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Lesions may form on seed stalks and floral parts of seed onions and affect seed development. Diseased tissue turns brown to black and dries out in the field or more commonly in storage. Affected stems may turn yellow, die back, collapse, and die within several weeks after the first lesions appear.</td></tr>
<tr><td>bulbs</td><td></td><td></td><td colspan="10">Onion bulbs become infected at harvest or later in storage through the neck or through wounds in the fleshy bulb scales. The rot is first semi watery and a deep yellow but gradually turns a wine-red, finally becoming dark brown to black.</td></tr>
</table>

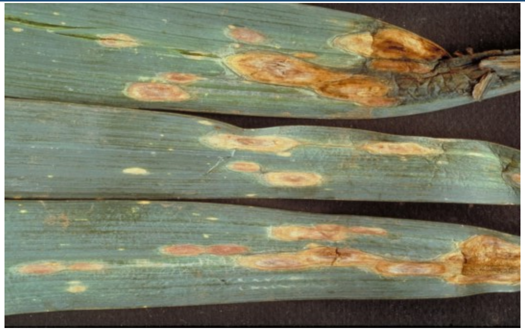
	Conditions for the infection	Infection, reproduction and spread of the disease may follow in rapid succession as long as favorable conditions persist. Free moisture, in the form of rain, persistent fog, or dew, is required for infection and spore production. Mycelial growth of the fungus occurs over a temperature range of 6 to 34 °C (optimum 25 to 27 °C) at a relative humidity of 90 %.
	Control strategies	**Prevention**: - make sure to use seeds from certified sources; - if possible, sow and transplant early in the season; - inspect nursery plants: check plants in the nursery and remove any seedlings that show leaf spots before transfer to the field. - choose resistant varieties if available; - plow field 2-3 times between seasons to expose the fungus to solar radiation; - increase the space between plants when transplanting; - fertilize generously with nitrogen and phosphorous to have strong and healthy plants; - control weeds in an around the fields; - remove debris and volunteer plants after harvest; - take care not to injure plants during field work; - crop rotations of 2-3 years prevent the pathogen populations from building up to high levels; - store bulbs at 1 - 3 °C and humidity 65-70 % in a well-aerated cooler; - control onion thrips, as plants weakened by them are more susceptible to disease. - use a drip irrigation system rather than overhead irrigation to avoid long periods of leaf wetness, which assists infection by spores. **Biological control**: To date, no effective biological control for this disease is available. The antagonistic fungus *Cladosporium herbarum* has been used to inhibit the pathogen *Alternaria porri* on contact *in vivo*, reducing the infection by 66 %. Other fungi were much less effective, for example *Penicillium* sp. (ca. 50 %). A mixture of several antagonists can cause a reduction of up to 79 %. However, no commercial products have been development on these findings so far. Aqueuos extracts of *Azadirachta indica* (Neem) and *Datura stramonium* (jimsonweed) can be used for the biocontrol of purple blotch. **Compounds with proven activity**: Because these diseases often occur after damage from onion downy mildew, controlling downy mildew is a critical strategy for preventing problems with purple blotch.

<table>
<tr><th colspan="3" rowspan="2">Basal rot</th><th colspan="12">The phenological growth stages and BBCH-identification keys of bulb vegetables (after Feller et al. 1995)</th></tr>
<tr><th>00</th><th>09</th><th>11</th><th>13</th><th>14</th><th>19</th><th>41</th><th>43</th><th>45</th><th>47</th><th>49</th><th>50-99</th></tr>
<tr><td rowspan="5">Fusarium oxysporum f. sp. cepae</td><td rowspan="3">Symptoms</td><td>seedlings</td><td colspan="3">Damping-off or delayed emergence. Basal rot is more prevalent in transplanted onions than in direct-seeded onions.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>plants</td><td></td><td></td><td colspan="8">This disease begins with the rotting of the basal plate, which prevents water and nutrients from being transported to the foliage. Symptoms caused by this rotting include yellowing of the foliage and leaf dieback from the tips at early or intermediate stages of crop development. Rotted areas of the bulb progress from the basal plate towards the neck of the bulb. Affected roots become dark brown to dark pink, and a white fungal growth is sometimes evident at the base of infected bulbs.</td><td></td><td></td></tr>
<tr><td>bulbs</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">Infected bulbs develop a dry rot of the basal plate and surrounding area, which sometimes develops into a soft rot due to secondary bacterial infections. The stem plate and dry outer scales crack open under dry conditions.</td><td></td></tr>
<tr><td colspan="2">Conditions for the infection</td><td colspan="12">A moderate temperature of 22 to 28 °C favours disease development. Disease also appears during storage when the temperature (35 to 40 °C) and relative humidity (70%) are high in the month of July to August.
The disease can be very damaging to susceptible varieties in fields with a history of Fusarium basal rot.</td></tr>
<tr><td colspan="2">Control strategies</td><td colspan="12">Prevention:
Plant resistant onion cultivars. Avoid fields with a history of Fusarium basal rot problems, and rotate 3 to 4 years out of onion, garlic, leek, and other crops that favor growth of the fungus, such as corn, tomato, and sunflower.
Since the pathogen is soil borne, it is difficult to control disease. Mixed cropping and crop rotation reduce the incidence of disease.
To avoid favorable conditions for infection, store bulbs at temperatures no warmer than 4 °C and at low relative humidity (about 70%).
Biological control: Biological controls have not been developed for Fusarium basal rot.
Direct control measures: Pasteurization of infested soil with steam. Soil solarization by spreading polythene sheet of 250 gauges in summer season for 30 days reduces the infectious germs, which in turn reduces the disease.</td></tr>
</table>

<table>
<tr><th colspan="3" rowspan="2">White rot</th><th colspan="12">The phenological growth stages and BBCH-identification keys of bulb vegetables (after Feller et al. 1995)</th></tr>
<tr><th>00</th><th>09</th><th>11</th><th>13</th><th>14</th><th>19</th><th>41</th><th>43</th><th>45</th><th>47</th><th>49</th><th>50-99</th></tr>
<tr><td rowspan="6">Sclerotium cepivorum</td><td rowspan="3">Symptoms</td><td>leaves</td><td></td><td></td><td colspan="9">Plants are stunted in growth with yellow and wilting foliage. The leaves eventually die and fall off with the older leaves dying first and then the aerial leaves.</td><td></td></tr>
<tr><td>stem</td><td></td><td></td><td colspan="9">The mycelial growth can be seen at the base of the stem when foliage is yellowing and the foliar symptoms are first appearing. Black globular sclerotia, that resemble poppy seeds can also appear on the mycelium. The plant turns yellow and wilts when fully developed because of rotting roots.</td><td></td></tr>
<tr><td>root and bulbs</td><td></td><td></td><td colspan="9">The roots are rotting. Mycelial growth is another symptom that appears on the roots and spreads to the bulb causing it to rot.</td><td></td></tr>
<tr><td colspan="2">Conditions for the infection</td><td colspan="12">The pathogen is dependent upon temperature. Environmental conditions influence the germination with it favoring cooler weather (10 °C). If there is high soil moisture present, germination and infection will be favored. The sclerotia and fungal growth are inhibited above 20 °C. Irrigation can also be a problem in spreading the disease from an infected field to a clean field.</td></tr>
<tr><td colspan="2">Prognostic models to be used</td><td colspan="12">Sampling and isolation of sclerotia: This fungus can form black, near-spherical sclerotia that are 200-500 µm in diameter. It can also form large sclerotial bodies of irregular shape with lengths varying between 0.5 and 1.5 cm. The sclerotia can be found on the mycelium or in soil. In order to establish the presence in the soil, a dry soil sample of known volume shall be sampled and washed by rinsing the soil on an 80-mesh sieve with running tap water.
Visual inspections: Identifying the fungus is possible by considering the combination of symptoms and signs observed in the field. During a cool season, or right after one, if there is white mycelium at the base of an Allium plant in the field which is white and fluffy then that's one clue the fungus is S. cepivorum.</td></tr>
<tr><td colspan="2">Control strategies</td><td colspan="12">Prevention:
select disease free fields and use disease-free planting material and avoid contamination from infected fields. Using clean machinery, boots and equipment will help to stop the spread of disease from an infected field. With infection occurring in cooler weather (10 - 21 °C), planting the crops at the right time is also important to not institute disease.
Direct control measures:
Other methods to reduce inoculum density is soil solarization. The usual method of solarisation is to spread clear plastic sheets over the ground to raise the soil temperature in the upper layer of the soil high enough to kill the sclerotia.</td></tr>
</table>

Picture 5.1. Downy mildew
(© https://www.shutterstock.com)

Picture 5.2. Basal rot
(© https://www.shutterstock.com)



Picture 5.3. Purple blotch
(© https://www.shutterstock.com)

Picture 5.4. White rot
(© https://www.shutterstock.com)

6. Methods and tools to manage weeds

	Scientific name	Common name
Annual weeds	*Amaranthus retroflexus*	red-root amaranth, redroot pigweed, red-rooted pigweed, common amaranth, pigweed amaranth, and common tumbleweed
	Avena fatua	wild oat
	Bassia scoparia	kochia, fireweed, burning bush or summer cypress
	Capsella bursa – pastoris	shepherd's purse
	Chenopodium album	lamb's quarters, melde, goosefoot, wild spinach and fat-hen
	Cuscuta sp.	dodder, amarbel
	Echinochloa crus-galli	watergrass, cockspur, cockspur grass, barnyard millet, Japanese millet, water grass, common barnyard grass, barnyard grass
	Portulaca oleracea	common purslane, little hogweed, parsley
	Senecio vulgaris	common groundsel, old-man-in-the-spring
	Stellaria media	chickweed, common chickweed, chickenwort, craches, maruns, winterweed
	Tribulus terrestris	puncturevine
	Xanthium strumarium	rough cocklebur, clotbur, common cocklebur, large cocklebur, woolgarie bur
Perennial weeds	*Agropyron repens*	couch grass, common couch, twitch, quick grass, quitch grass (also just quitch), dog grass, quackgrass, scutch grass, and witchgrass
	Cirsium arvense	creeping thistle, Canada thistle, field thistle
	Convolvulus arvensis	field bindweed, lesser bindweed, European bindweed, withy wind, perennial morning glory, small-flowered morning glory, creeping jenny, and possession vine
	Lepidium latifolium	pepperweed, pepperwort, peppergrass, dittander, dittany, tall whitetop
	Taraxacum officinale	dandelion, common dandelion

Cultural measures	The onion is a naturally poor competitor. To avoid yield reduction, weed control is essential right from the sowing. Yield losses caused by weeds depend on the duration of competition, weed species and densities, agricultural practices, crop growth stage, climatic conditions and possibly other factors. Weed competition reduces onion bulb yield and diameter and seriously impact bulb quality. Therefore, weeds shall be kept under control during the early growth of the onion as the plant grows slowly at first and is readily injured by weeds. Hand cultivation with wheel hoes was once a standard practice, but it has been largely replaced by cultivation with special models of regular farm tractors made for closely spaced crops. For weed destruction, blade attachments which cultivate about 8 cm deep are superior to other types of cultivator attachments. Hand weeding was for a long time the most laborious and expensive operation connected with growing onions, but it has been largely eliminated through the use of chemical methods of weed control. Flame weeding has become common as weeding practice in southern Europe, especially in organic crop production. Flame weeding is a "thermal" technique that works by killing weeds with heat (not fire). Flame weeding is viable for weed control along plant rows in onion, where mechanical tillage is ineffective or causes unacceptable crop damage, and can reduce or eliminate the hand-weeding cost, while inter-row weeds can be effectively controlled through mechanical tillage. The flame weeding is more effective to broadleaf weeds than to grass species, but its success also depends on propane dose and plant development. Disturbing soil can enhance weed germination by bringing seeds closer to the soil surface. Flaming can also be used as an alternative to cultivation if the soil is too wet to cultivate.

Picture 6.1. Watergrass
(© https://www.shutterstock.com)

Picture 6.2. Chickweed
(© https://www.shutterstock.com)

Picture 6.3. Goosefood
(© https://www.shutterstock.com)

Picture 6.4. Common groundsel
(© https://www.shutterstock.com)

Picture 6.5. Red-root amaranth
(© https://www.shutterstock.com)

Picture 6.6. Wild oat
(© https://www.shutterstock.com)


Picture 6.7. Couch grass
(© https://www.shutterstock.com)


Picture 6.8. Pepperwort
(© https://www.shutterstock.com)


Picture 6.9. Field thistle
(© https://www.shutterstock.com)

7. Reference list

BAES, Bundesamt für Ernährungssicherheit. Fachbereich Pflanzenschutzmittel. Available online, URL: https://psmregister.baes.gv.at/psmregister/ (accessed on 3rd November 2022)

Block, E. 2010. Garlic and Other Alliums: The Lore and The Science, 1st Edition, 445 p.

Brewster, J. 2008. Onions and Other Vegetable Alliums, 2nd Edition. Horticulture Research International, Wellesbourne, UK, 448 p.

Černe, M. 1992. Čebulnice: čebula, česen, por, zimski luk, drobnjak, šalotka. Pridelovanje in varstvo. Ljubljana, Kmečki glas, 61 p.

Černe, M., Jakić, O., Urek, G. 1990. Pridelovanje čebule. Ljubljana, Kmetijski inštitut Slovenije, 23 p.

El-Tantawy, E.MM.; El-Beik, A.K. 2009. Relationship between growth, yield and storability of onion (*Allium cepa* L.) with fertilization of nitrogen, sulfur and copper under calcareous conditions, Res. J. Agric. Biol. Sci. 5 (4): 361-171.

Feller, C.; H. Bleiholder; L. Buhr, H.; Hack, M.; Hess, R.; Klose, U.; Meier, R.; Stauss, T.; van den Boom E. 1995. Phänologische Entwicklungsstadien von Gemüsepflanzen: I. Zwiebel-, Wurzel-, Knollen- und Blattgemüse. Nachrichtenbl. Deut. Pflanzenschutzd, 47: 193-206.

Herlinda, S.: Era, M. S.; Yulia, P.; Suwandi.; Elisa, N.; dan Anung, R. 2005. Variasi Virulensi Strain-strain *Beauveria bassiana* (Bals.) Vuill. Terhadap Larva *Plutella xylostella* (L.) (Lepidoptera:Plutelliade). Agritrop 2:52-57.

Kacjan-Maršić, N.; Ugrinović K. 2001. Čebula. Sodobno kmetijstvo, 34 (5): 211-214.

Khokhar, K.M. 2019. Mineral nutrient management for onion bulb crops – a review. J. Hortic. Sci. Biotechnol. p. 2380–4084.

Kumar, K.P.S.; Bhowmik, D.; Tiwari, P. 2010. *Allium cepa*: A traditional medicinal herb and its health benefits. J. Chem. Pharm. Res., 2(1): 283-291.

Marschner, H. 1995. Mineral Nutrition of Higher Plants, 2nd Edition. Academic press, London, UK, p. 196.

Lawande, K.E. 2012. Handbook of Herbs and Spices, 2nd Edition. Woodhead Publishing Series in Food Science, Technology and Nutrition, p. 417-429.

Rabinowitch, H. D.; Currah, L. 2002. Allium crop science: recent advances. Institute of Plant Science and Genetics in Agriculture, The Hebrew University of Jerusalem, Faculty of Agricultural, Food and Environmental Quality Sciences, PO Box 12, Rehovot 76100, Israel. 486 p.

Rueda, A., Shelton, A.M. 1995. Onion thrips, Global crop pest. International Institute for Food, Agriculture and Development. Cornell University. Ithaca, NY.

Schwartz, H.F.; Mohan, S.K. 2016. Compendium of Onion and Garlic Diseases and Pests, 2nd Edition. The American Phytopathological Society, 127 p.

hat formatiert: Englisch (Vereinigtes Königreich)

hat formatiert: Englisch (Vereinigtes Königreich)