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APRIL 2020 |

GARLIC STORAGE, POST-HARVEST DISEASES, AND PLANTING STOCK CONSIDERATIONS

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Once post-harvest disease manifests in garlic, there is little to be done, so it is best to avoid creating conditions that are conducive to disease development in the first place. Disease management starts in the field by ensuring appropriate harvest timing and good harvest practices.

Harvest

To avoid post-harvest disease in your garlic, **harvest timing** is important. While garlic should be left in the ground long enough to maximize yield, it is important that the cloves do not start to separate from the stem, as this will reduce marketability and storability. A wetter year will cause the cloves to separate quicker than is typically expected so as harvest nears, be sure to check your crop regularly. Late-harvested garlic is also more likely to have stained or partially decayed wrapper leaves. Harvesting too early will reduce yield, and immature bulbs might shrivel during curing. To read more about garlic harvest timing, please see the **Nova Scotia Vegetable Blog**.

To avoid post-harvest disease in your garlic, **avoid injury** to the bulbs. Pulling garlic without first loosening the soil can reduce the integrity of the bulb and open wounds where the stem and bulb meet, resulting in an open door for infection to set in. Fresh bulbs also bruise easily: avoid knocking bulbs together to remove soil, and place them gently in the curing area. Wounds caused by bruising are another area that can easily become diseased.

Curing

To avoid post-harvest disease in your garlic, **curing conditions** are important. Curing enhances and concentrates flavour by reducing the water content; this also reduces growth of fungal pathogens. Curing in the direct sun can result in sunscald. High temperatures (over 32°C or 90°F) can also injure bulbs. Curing in poorly ventilated areas results in a build-up of humidity, slowing the drying process and creating ideal conditions for fungal infection. Optimal curing temperatures are 24-29°C or 75-85°F. Using forced ambient air (5 ft^3/min/ft^3 of garlic) will significantly reduce drying time. Curing can take 10-14 days, longer if the relative humidity is high. Stems can be either cut before or after curing, whichever optimizes labour efficiency on your farm. If curing in containers, make sure that they are open enough to allow for good airflow. Garlic should not be stacked more than three feet high in a container to avoid bruising. Curing is complete when two outer skins (scales) are dry and crispy, the neck is constricted, and the centre of the cut stem is hard.

Storage

To avoid post-harvest disease in your garlic, **proper storage conditions** are vital. Depending on variety, garlic could be kept for months. For short-term storage, ambient temperatures 20-30°C or 68-86°F with low relative humidity (<75%) will work, but due to water loss, the bulbs will eventually become shriveled, soft, and spongy. For longer-term storage, lower temperatures (-1 to 4°C or 30-39°F, although some studies recommend storage at even colder temperatures, down to -4°C) with low relative humidity (60-70%) and good airflow will ensure months of high quality garlic. Higher humidity encourages both mold growth and root growth, lower humidity will result in the bulbs drying out. Stored bulbs will continue to transpire, so adequate ventilation is needed throughout the storage period to avoid storage losses. Garlic cloves break dormancy most rapidly between 4-10°C (40-50°F), so to prevent pre-mature sprouting, avoid prolonged storage at this temperature.

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Post-harvest disease

Different species of pathogenic fungi affect garlic quality during storage. Often these diseases occur as a complex of more than one species.

Fusarium bulb rot is caused by *Fusarium proliferatum* and it has been reported as an emerging disease of garlic. The primary symptoms on garlic cloves appear as a water-soaked lesion which progresses from the tip towards the base of the clove. Whitish mycelium (fungal threads) may be visible **(Figure 1)**. If the disease is at an advanced stage, the infected cloves dry out and appear crinkled.

- Planting infected cloves
  - » Infected cloves will exhibit poor germination and should not be used for planting. If one clove in a bulb shows symptoms, it is not unlikely that the rest of the cloves in the bulb are also infected. It would be best not to plant any cloves from that bulb. Infected seedlings may or may not show damping off symptoms.
- Marketing or eating infected cloves
  - » *F. proliferatum* produces a variety of mycotoxins and infected cloves should not be eaten or sold.

Figure 1. Fusarium bulb rot. Note how the disease progresses from the tip downward (Courtesy R. Gillis-Madden).

Fusarium basal rot is caused by *Fusarium oxysporum* f.sp. *cepae*, and *F. culmorum*. The basal plate is the area of the bulb between the roots and the cloves. Symptoms may appear very similar to bulb rot but with an important difference: basal rot progresses from the basal plate upwards, which is the opposite of bulb rot symptoms. In storage, bulbs show spongy, sunken yellow-brown rotting lesions **(Figure 2)**. During the early stages of infection, bulbs will appear softened, brown and watery when cut open. There may be a white, light pink or reddish fungal growth (mycelium) covering the cloves, or in the rot cavities. Deep cracks form in the cloves, followed by a breakdown of the tissue. Cloves will eventually dry down to a portion of their original size, the cloves becoming crinkled and small. Postharvest symptoms may involve single, several, or all cloves in a bulb.

Fusarium basal rot is a fairly serious disease that can persist in the soil for years. If you find this disease in your garlic crop, it is best to not plant that field back to any *Allium* (onions, leeks, garlic, etc.) for at least four years, if not longer.

- Planting infected cloves
  - » Bulbs and cloves can be infected with Fusarium basal rot without displaying any symptoms. If one clove in a bulb is showing symptoms, it is best to not plant the entire bulb.
- Marketing or eating infected cloves
  - » There are many strains of *F. oxysporum* and *F. culmorum* which produce mycotoxins in other host plants. To be safe, infected cloves should not be eaten or sold.

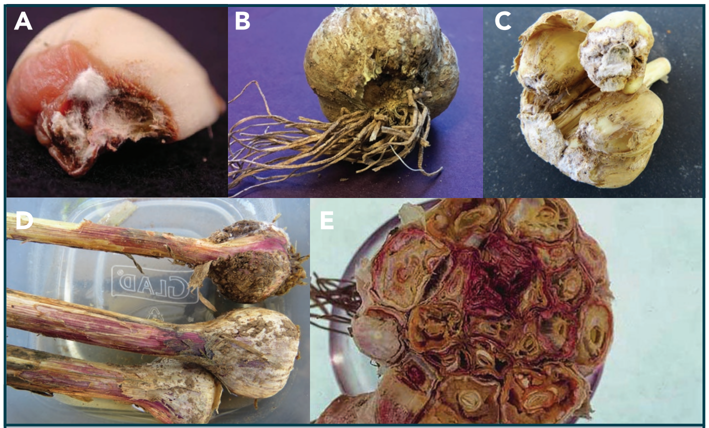

Figure 2. Fusarium basal rot in garlic caused by *Fusarium* sp. **(A)** Initial water soaked lesions with white mycelium (Courtesy M. Putnam, OSU), **(B)** Disintegration of basal plate (Courtesy R. Gillis-Madden), **(C, D)** *Fusarium* sp. damage during storage, note lack of roots (Courtesy P. Hildebrand), **(E)** Reddish decay of cloves (Courtesy P. A. Koepsell).

Black mold is caused by *Aspergillus niger* and *A. ochraceus*. Both fungal species are considered saprophytes and colonize dead tissue. Any crop residue left in the field can be a host for black mold. Mechanical damage or bruising during harvesting is a common way to introduce *Aspergillus* into the bulbs, where it then proliferates on the bulb scales if stored under damp conditions. Typical symptoms include the presence of black dust (spores) between the outer scales and cloves **(Figure 3)**.

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- Planting infected cloves
  - » Garlic bulbs infected with black mold should not be used for planting.
- Marketing or eating infected cloves
  - » Some strains of *Aspergillus niger* produce toxins which can be hazardous. Infected bulbs should not be used for human consumption.

Figure 3. Black mold. **(A)** Black powdery spores can easily be observed on the scales, **(B)** Severe black mold infection that has penetrated the clove (Courtesy R. Gillis-Madden).

Neck rot is caused by *Botrytis porri*. The infection starts near the soil line **(Figure 4A)**. The fungus continues its growth towards the inner axis of the bulb **(Figure 4B, C)**, leading to dry rot of cloves during storage **(Figure 4D)**. Cool and wet conditions in late spring or early summer favour this disease.

- Planting infected cloves
  - » Infected bulbs should not be used for planting.
- Marketing or eating infected cloves
  - » Although no mycotoxin has been reported from this fungus, inhalation of spores may cause hay fever, asthma and serious eye infection.

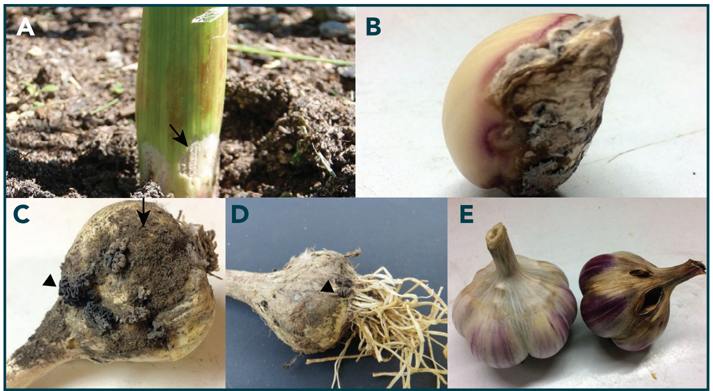

Figure 4. Garlic neck rot. **(A)** Neck lesions due to *Botrytis* near the soil line, **(B)** Clove decay due to neck rot, **(C, D)** Grey mycelium (↑) and large black sclerotia (▲) at an advanced stage of infection, **(E)** Asymptomatic bulb (left) and infected bulb (right) in storage **(A, B, C, E**; Courtesy Rasa Creek Farm www.rasacreekfarm.com; **D**; Courtesy P. Hildebrand).

Blue mold is caused by *Penicillium hirsutum* and is commonly found in stored garlic bulbs. The infected bulb and cloves initially exhibit water-soaked areas on the outer surface of scales, leading to a mass of blue-green powdery mold growth **(Figure 5)**. Eventually the infected clove completely decays. This pathogen typically does not survive in the soil for very long. Mechanical damage provides opportunity for this disease to colonize and establish on the crop, so care should be taken during harvest and storage. Storing garlic in low temperatures (less than 4.5°C or 40°F), with low humidity and good ventilation prevents the growth and sporulation of *Penicillium*.

Figure 5. Blue mold of garlic. **(A)** Water soaked lesion with bluish-green mycelium on the clove (Courtesy S. Johnson, University of Maine), **(B)** and **(C)** Heavily infected scales and roots (Courtesy R. Gillis-Madden).

- Planting infected cloves
  - » Infected cloves serve as a source of inoculum for the next cropping season. *Penicillium* mostly survives in infected bulbs as it does not typically survive in the soil. When cloves are cracked to separate the bulb for planting, the *Penicillium* spores spread and infect the healthy cloves through wounds. If cloves are planted soon after cracking, the fungus may not get a chance to establish itself.
- Marketing or eating infected cloves
  - » Several species of *Penicillium* produce mycotoxins. Infected bulbs should not be used for human consumption.

Embellisia skin blotch and bulb canker is caused by *Embellisia allii*. Skin blotch is restricted to the outer scales of the bulb as a minor cosmetic blemish. Symptoms exhibit a diffuse coating of charcoal-coloured flecks over the surface of the outer scale **(Figure 6)**. Bulb canker symptoms consist of charcoal-coloured, corky masses on individual cloves, most commonly at the top or on the sides. This fungus can survive on plant debris, in soil and in infected bulbs. Warm temperatures (25°-30°C) and high humidity are optimum for fungal development. Embellisia skin blotch is mainly a problem in wet years with poor drying conditions after harvest. Proper drying and storage conditions with humidity less than 70% will slow fungal development.

- Planting infected cloves
    - Bulbs infected with *Embellisia* should not be used for planting.
- Marketing or eating infected cloves
    - Skin blotch is mainly a cosmetic issue and outer skins or scales can easily be removed. Some species of *Embellisia* produce toxins which are not safe for livestock.

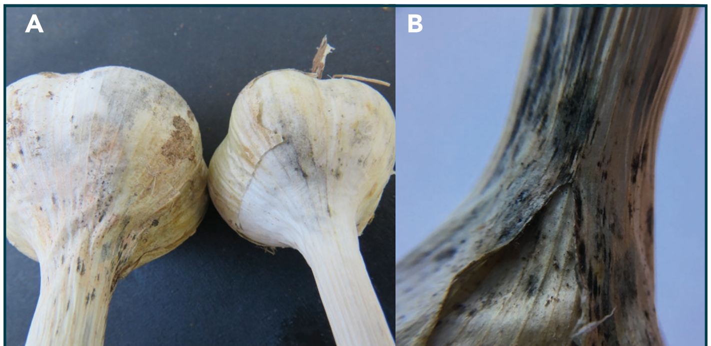

Figure 6. Embellisia skin blotch: Symptoms exhibit a diffuse coating of charcoal-coloured flecks (Courtesy R. Gillis-Madden).

Bulb mites (*Aceria tulipae*, *Rhizoglyphus* spp.) are pale to cream coloured and develop on decaying organic matter in the field. They usually feed on the roots and the basal plate of garlic bulbs. During storage, bulb mite feeding causes sunken tan to brown spots on cloves **(Figure 7A)**. Mite injury provides an entry point for fungal pathogens (*Fusarium* and *Penicillium*) and bacterial rots in the field as well as during storage. Bulb mites can overwinter in the field and survive during storage at low temperatures. In addition, bulb mites can transmit garlic viruses.

- Planting infected cloves
    - Bulb mites can survive in low temperatures during storage. Heavily infested seed should not be planted in the field.

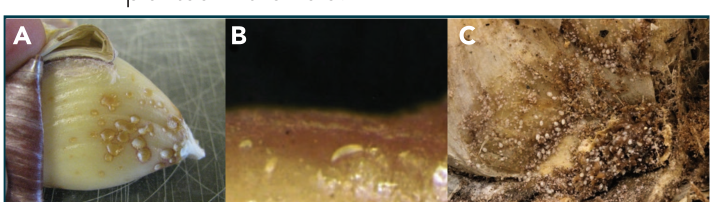

Figure 7. (A) Bulb mite damage with sunken tan spots on the clove (Courtesy L. Du Toit, WSU), **(B)** Banana shaped *Aceria tulipae* on the surface of garlic clove. A 5x or 10x hand lens could be used to observe a bulb mite (Courtesy M. Putman, OSU), **(C)** *Rhizoglyphus* sp. damage on garlic bulb, creamy white mites can be visible with the naked eye or a 5-10x hand lens (Courtesy P. Hildebrand).

- Marketing or eating infected cloves
    - Bulb mites compromise bulb quality. Mycotoxins produced by secondary fungal invaders are health risks and thus consuming infected bulbs presents a risk to human health.

Stem and bulb nematode (*Ditylenchus dipsaci*), also sometimes referred to as garlic bloat nematode, is a common garlic pest, often indistinguishable with the naked eye from Fusarium basal rot. The infected bulbs often have fewer roots, become desiccated, shrunken, shriveled and lighter in weight **(Figure 8)**. Diseased garlic bulbs decay at the base and contain many secondary pathogenic microorganisms such as bacteria, fungi, and bulb mites. Soil that has been planted to garlic that is found to be infested with stem and bulb nematode should not be planted to *Alliums* (onions, leeks, shallots, etc.) for at least four years.

- Planting infected cloves
    - Garlic bulbs harvested from a stem and bulb nematode infested field should not be used for planting. Seemingly healthy bulbs often contain quiescent nematodes, surviving in the outer scales of bulbs and cloves. Certified clean seed should be used, although it is difficult to find.

Figure 8. Stem and bulb nematode damage, **(A)** The basal plate of the garlic bulb has been infested heavily with stem and bulb nematode and root loss is evident, **(B)** Garlic from two different seed sources: On the left, the seed was heavily infested with nematodes, on the right, a healthy planting (Courtesy P. Hildebrand), **(C)** Yellowed skins may also be indicative of infestation by nematodes (Courtesy S. Jensen, Cornell University).

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Other planting stock considerations

There are other factors that should be taken into consideration when you are separating out your planting stock for next season.

White rot *(Sclerotium cepivorum)* is occasionally found in garlic, and can be a very destructive disease in all *Allium* species. The characteristic symptoms are the presence of white fluffy mycelium and soft rot around the base of the infected garlic bulbs. Masses of tiny, poppy seed-sized black sclerotia (0.2 – 0.5 mm) can be observed on the bulbs with the help of a 5-10x hand lens (**Figure 9**). Heavily infected plants can be pulled out easily as the bulbs and roots have been destroyed by the pathogen. The initial infection starts late in the season, and can go unnoticed at harvest, often becoming apparent in storage. Pre-emergence death is often observed when the infected asymptomatic cloves are used for planting. Sclerotia can remain dormant in infected soil for 10-15 years. Sclerotia will germinate when they sense sulphur compounds exuded from the roots of *Allium* species. Wet and cool soil temperatures (9-21°C or 48-70°F) favour sclerotia germination and root invasion. The disease can be introduced into unaffected fields by using infected garlic cloves or other infected *Allium* transplants. Sclerotia can also be carried from field to field or block to block in soil adhering to boots or tillage equipment. Practicing good sanitation of equipment that has been used in contaminated soil is essential to avoid the spread of this disease throughout your farm. To learn more about biosecurity in horticulture crops, please check out Perennia's factsheet: **Biosecurity Is Important in Horticulture Crops Too**

- Planting infected cloves
    - Infected bulbs should not be used for planting.
- Marketing or eating infected cloves
    - Infected bulbs should not be consumed.

Viruses There are several different viruses that infect garlic, but differentiating between them without using molecular techniques is very difficult. Viruses can spread by planting infected seed stock. As garlic is propagated vegetatively, with each replanting, the problem is compounded. Insects such as aphids or thrips can vector the disease between plants, spreading the contamination from one infected plant to the entire field. In storage, mites can also spread viruses as they move from an infected bulb to a healthy bulb. A plant can be infected by more than one virus.

Primary symptoms include mild to strong mosaic, chlorotic (yellow) mottling, striping, and streaking of leaves. It is more pronounced in young leaves **(Figure 10)**, and should not be confused with nitrogen deficiency, which appears on the older leaves. Some infected leaves may curl downward, appearing limp or wilted, and show flattening or crinkling. Infected plants remain stunted compared to non-infected plants. Depending on when infection occurs, infected plants may have reduced bulb size compared to healthy plants. Seedlings infected early in the season may form very small bulbs or fail to form bulbs, whereas, mid-season infection may produce well-formed bulbs that are only slightly smaller than those of noninfected plants. Bulbs from infected plants store poorly and sprout prematurely.

- Planting infected cloves
    - Cloves from infected bulbs should not be used for planting.
    - Infected plants should be removed from the field to prevent the virus spreading from an infected plant to healthy plants.
    - Virus-free planting stock should be used whenever possible.
- Marketing or eating infected cloves:
    - Infected bulbs should not pose any risk to human consumption.

Figure 9. White rot of garlic. **(A)** Poppy seed-sized black sclerotia on garlic (Courtesy S. Jensen, Cornell University), **(B)** Dead lower leaves with white fluffy mycelium and black sclerotia on the forming garlic bulb (Courtesy S. Renquist, OSU Extension).

Figure 10. Garlic leaves infected with viruses. Symptoms include mosaic, chlorotic mottling, striping, and streaking of leaves (Courtesy R. Gillis-Madden).

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References

Abbas, H.K., Mirocha, C.J. 1988. Isolation and purification of a hemorrhagic factor (wortmannin) from *Fusarium oxysporum* (N17B). Applied and Environmental Microbiology, 54(5): 1268-1274.

Celetti, M. (2014) Managing stem and bulb nematode in garlic starts in the fall.
Retrieved from **http://www.omafra.gov.on.ca/english/crops/hort/news/hortmatt/2014/22hrt14a1.htm**

Elshahway, I.E., Saied, N.M., Morsy, A.A. 2017.
Fusarium proliferation, the main cause of clove rot during storage, reduces clove germination and causes wilt to established garlic plants. Journal of Plant Pathology, 99 (1), 85-93. **http://www.sipav.org/main/jpp/index.php/jpp/article/view/3794**.

Howard, F., Schwartz, S. K. Mohan. 2008. Compendium of onion and garlic diseases and pests. American Phytopathological Society, St. Paul, Minnesota 55121, U.S.A.

Jepson, S.B. (2008). Fusarium rot of garlic [Fact sheet].
Retrieved from **http://sites.science.oregonstate.edu/bpp/Plant_Clinic/Garlic/Fusarium.pdf**.

Johnson, S.B. (n.d.) Blue mold of garlic. Retrieved from **https://extension.umaine.edu/publications/1206e/**.

Madeiras, A. (n.d.). Bulb mites in garlic [Fact sheet].
Retrieved from **https://ag.umass.edu/sites/ag.umass.edu/files/fact-sheets/pdf/bulb_mites_garlic.pdf**.

McLain-Romero, J., Creamer, R., Zepeda, H., Strickland, J., Bell, G. The toxicosis of *Embellisia* fungi from locoweed *(Oxytropis lambertii)* is similar to locoweed toxicosis in rats, Journal of Animal Science, 82 (7): 2169–2174.
DOI: **https://doi.org/10.2527/2004.8272169x**.

Moustafa, H.A.M, Eman, S.H.F., Mazhar D.A.M. 2013. Pathogenic fungi in garlic seed cloves and first report of *Fusarium proliferatum* causing cloves rot of stored bulbs in upper Egypt. Archives of Phytopathology and Plant Protection, 46:17, 2096-2103. DOI: 10.1080/03235408.2013.785122.

Pappu, H.R., Hellier, B.C., Dugan, F.M. 2008. Evaluation of the national plant germplasm system's garlic Collection for seven viruses. Plant Management Network, 9:1. DOI:10.1094/PHP-2008-0919-01-RS.

Perincherry, L., Lalak-Kańczugowska, J., Stępień, Ł. 2019. Fusarium-Produced Mycotoxins in Plant-Pathogen Interactions. Toxins, 11(11): 664. DOI:10.3390/toxins11110664.

Plant disease diagnostic clinic, Cornell university. (2015). Diseases of garlic: various pests [Fact sheet].
Retrieved from **http://plantclinic.cornell.edu/factsheets/garlicdiseases.pdf**.

Rasa Creek farm. (n.d.) Diseases and pests of garlic.
Retrieved from **http://www.rasacreekfarm.com/how-to-grow-garlic/garlic-diseases-and-pests**.

University of Minnesota extension. (n.d.) Garlic.
Retrieved from **https://apps.extension.umn.edu/garden/diagnose/plant/vegetable/garlic/leaveswilt.html**.

Waskiewicz, A., Golinski, P., Karolewski, Z., Irzykowska, L., Bocianowski, J., Kostecki, M., Weber, Z. 2010. Formation of fumonisins and other secondary metabolites by *Fusarium oxysporum* and F. proliferatum: a comparative study, Food Additives & Contaminants: Part A, 27(5): 608-615. DOI: 10.1080/19440040903551947.

World Health Organization. (n.d.) Mycotoxins.
Retrieved from **https://www.who.int/news-room/fact-sheets/detail/mycotoxins**.