Diseases and Disease Management in Seed Garlic: Problems and Prospects

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ABSTRACT

Although garlic is occasionally propagated via true seed, routine planting of garlic uses seed cloves as vegetative propagules. The size of seed cloves (large relative to seed of most agronomic crops), their vegetative habit, and routine storage conditions for seed cloves (permissive for most fungi), create opportunities for pathogens and problems for growers. Several phytopathogenic fungi, including some newly documented as pathogenic to garlic, are able to infest or colonize bulb tissues and remain latent for some time subsequent to harvest. Infested or infected bulbs may appear healthy at time of shipping or receipt, and even for protracted periods of storage, but incubation at suitable temperatures can result in the appearance of rot. The potential for planting seed cloves containing pathogens, plus the capacity of several of these fungal pathogens for prolonged survival in field soil, implies that pathogens may be introduced into and contaminate field soils. Systemic fungicides used as pre-planting and/or post-harvest dips can promote plant health, but the large size of seed cloves ensures that deep-seated infections are not eradicated. Viruses also persist in vegetative material, are unaffected by fungicides, have been detected in a high proportion of garlic grown as planting stock, and often have arthropod vectors that are difficult to control. To circumvent these problems, tissue culture is increasingly used to generate disease-free planting stock.

Keywords: Allium sativum, fungi, garlic, pathogens, seed clove, viruses

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INTRODUCTION

Some varieties of garlic (Allium sativum L.) can be propagated by true seed (Simon and Jenderek 2003), a trait extremely useful for the breeder. Production of true seed from garlic is the subject of U.S. Patent 5746024. However, the most common method for growing garlic involves planting of clonal propagules, i.e., seed cloves (Sims et al. 1976; Sutherland and Waverley 1995; Hannan and Sorensen 2002), or in some instances, inflorescence bulblets (Schwartz et al. 1995; Simon and Jenderek 2003). This review primarily addresses management of diseases affecting or transmitted by seed cloves. Typically, these cloves originate with plants harvested in late summer (e.g., early July to mid-September in the Pacific Northwest of the USA), then stored and planted again in fall (mid-September to November) or for certain varieties early spring (March) (Hannan and Sorensen 2002; Barbara Hellier, pers. comm.). Storage conditions of approximately 12-14°C and 55% relative humidity retard sprouting during storage and optimize rapid germination and growth upon planting (Hannan and Sorensen 2002). Others recommend a storage temperature closer to 10°C, but holding bulbs near 5°C for extended times increases risk of sprouting (Sutherland and Waverley 1995). Cloves destined for spring-planting have been stored at 0°C or -3°C with successful results, but some cultivars are sensitive to such low temperatures (Volk and Rotindo 2004).

THE SEED CLOVE AS HABITAT FOR PESTS AND PATHOGENS

The large size of the clove (relative to the true seed of most other field crops) and storage at ca. 10-14°C create difficulties in disease management. Cloves are sufficiently large that even prolonged exposure to systemic fungicides in pre-planting or post-harvest dips is insufficient to eliminate deeply seated infections (Dugan et al. in press), so unlike most true seed the use of fungicidal dips is no guarantee of...
strongly reduced inoculum in planting stock. Fungicidal dips are effective only on recently established, relatively shallow infection courts, although systemic fungicides are labeled for use against *Fusarium* and *Penicillium* bulb rots in ornamental flowers as well as in *Allium* species (G. Chastagner pers. comm.; Hong 2007).

Attacks by bulb mites (*Rhizoglyphus* spp. and *Tyrophagus* spp.) and the wheat curl mite (*Eriophyes tulipae* Keifer) in storage can also promote rot. Just as the above storage conditions are permissive for many fungi, they are also permissive for mites (Coviello et al. 2002). *Rhizoglyphus robini* Claparede, *Tyrophagus putrescentiae* Shrank and/or *Histiostoma onioni* Eraky were demonstrated capable of vectoring *Aspergillus niger* Van Tieghhem, *A. ochraceus* Wilhelm, *Fusarium oxysporum* Schlechtend. : Fr., *Gibberella fujikuroi* (Sawada) Ho, *Penicillium* spp. and other fungi (*Acremonium* and Eraky 2001). Mite control is difficult, even with chemicals. A comprehensive guide to diseases and pests of garlic is available (Schwartz and Mohan, in press).

**FUNGAL PATHOGENS OF SEED GARLIC**

The most common fungal pathogens attacking garlic bulbs in storage are *Aspergillus niger*, *A. ochraceus*, *Embilda allii* (Campanile) Simmons, *Fusarium oxysporum* Schlechtend. : Fr. f. sp. *cepeae* (H.N. Hans.) W.C. Snyder & H.N. Hans. *F. proliferatum* (Matsushima) Nirenberg (Fig. 1), and *Penicillium hirsutum* Dierckx (Fig. 2). We have also found instances of rot involving *Botrytis pory* Buchw., and the recently reported *Fusarium verticillioides* (Sacc.) Nirenberg (Dugan et al., in press). However, not all isolates to which these names can be applied are necessarily aggressive. We have isolated of *A. ochraceus* and *A. niger* and *E. allii* that are not very aggressive in comparison to other pathogenic species (although *E. allii* has been quite damaging under moist field conditions). Moreover, we have evidence that some isolates of *Fusarium oxysporum* f. sp. *cepeae* and *F. proliferatum*, quite aggressive in onion, are less aggressive in garlic, especially when the latter has aged ("hardened") subsequent to harvest (Dugan et al. in press; Slavica et al. in press). The extent to which some of these pathogens might remain quiescent in tissues for one or more clonal generations, similar to the situation documented by Crowe (1995) for *Fusarium culmorum* (Wm. G. Sm.) Sacc., is largely unknown. However, in a survey of asymptomatic, commercially distributed seed garlic, Dugan et al. (in press) recovered three or more of these pathogenic species from each of seven lots: six lots from various states in the USA and one lot from mainland China. Molecular-genetic protocols for detection and differentiation of some mycotoxin-producing fungi documented from garlic have been published (Mulé et al. 2004).

One of the most aggressive agents of rot in garlic is a species of *Penicillium*, the correct name for which is the subject of recent publications. The name *P. corymbiferum* (= *P. verrucosum* var. *corymbiferum* (Westling) Samson, Stolk & Hadlock) was formerly often applied (e.g., Smallpy and Hansen 1962; Brammall 1989) but has been largely replaced by its synonym *P. hirsutum* (Pitt 2000). In fact, various names have been applied to *Penicillium* species rotting garlic (Brammall 1989). Overy et al. (2005) examined a collection of several isolates, amongst which only those bearing the name *Penicillium allii* Vincent & Pitt were strongly pathogenic to garlic; isolates bearing the name *P. hirsutum* were not very aggressive. Valdez et al. (2006) applied the name *P. allii* to isolates pathogenic to garlic in Argentina. Cavagnaro et al. (2005) use the name *P. hirsutum*. Dugan et al. (in press) noted such varied preferences, but applied the name *P. hirsutum* in a broad sense to all the isolates pathogenic to garlic in their work because some produced a deeply colored exudate said to characterize that species (Frisvad and Samson 2004). Several species in section Corymbifer, including *P. allii*, were formerly treated as varieties of *P. hirsutum*, including *P. hirsutum* var. *allii* (Vincent & Pitt) Fisvad (Frisvad and Filtenborg 1989). Living type material (strictly speaking, ex-type) of *P. allii* is from garlic, but type material for *P. hirsutum* is a neotype isolated from aphids (Frisvad and Samson 2004).

**SURVIVAL OF FUNGAL PATHOGENS IN SOIL**

*Fusarium oxysporum*, f. sp. *cepeae* produces chlamydospores, and is capable of protracted survival (Haye 1995). *F. proliferatum* does not produce chlamydospores (Nelson et al. 1983) but was capable of prolonged survival in soil when associated with residue (Cotton and Munkvold 1998). Dugan et al. (in press) found that *F. proliferatum* and *F.
oxysporum in field soil survived prolonged freezing in simu-
tlated winter conditions. Fusarium verticillioides is also
documented as surviving well in field conditions (Leslie
and Summerell 2006). E. allii is reported to over-winter in
plant debris or soil (David 1991). B. porri produces sclero-
tia of considerable size (Chilvers and du Toit 2006), and A.
ochraceus can also produce sclerotia (Klich 2002). As
its name indicates, Sclerotium cepivorum also produces sclero-
tia, and a number of management strategies have evolved to
facilitate their reduction, e.g. compounds that stimulate ger-
mination by mimicking exudates of Allium roots (Hoivus
and McDonald 2002; Davis et al. 2007). Sclerotia of S.
cepivorum can persist for years, even in absence of the host
(Maria Jenderek, pers. comm.). Penicillium hirsutum, how-
ever, does not persist for a long time in soil (Anon 2004).

MYCOTOXIN PRODUCTION

Although this review primarily addresses seed garlic, it is
important to note that several fungi produce toxins which
might become important in table garlic. Seefelder et al.
(2002) claimed detection of fumonisin mycotoxins by F.
proliferatum in market garlic in Germany, and the pathogen
is now reported from garlic in North America (Dugan et al.
2003; du Toit and Dugan, in press). F. verticillioides has only
recently been documented as rotting garlic (Dugan et al.,
in press), but much has been written on mycotoxin pro-
duction by F. verticillioides (e.g., Shim and Woloshuk
2001). “F. proliferatum and F. verticillioides are the two
most prolific producers of fumonisins” and F. proliferatum
produces additional mycotoxins (Desjardins 2006). Myco-
toxin production by Allium-inhabiting isolates of F. pro-
liferatum has been analyzed (Stankovic 2007) Some iso-
lates of Aspergillus ochraceus and A. niger produce ochra-
toxin A (Klich 2002). Penicillium hirsutum may produce
roquefortine C, and P. allii is also documented as produ-
cing this compound (Frissvad and Samson 2004).

BACTERIA

Pseudomonas fluorescens Migula has been documented as
pathogenic in garlic and causing a disease named ‘maladie
café au lait’in France (Diekmann 1997) and Burkholderia
cepacia (Palleroni and Holmes Yabuuchi et al. is a regu-
lated organism on at least one pest list for garlic (Herrera
2005). In addition, Erwinia carotovora ssp. carotovora
(Jones) Bergey et al., E. chrysanthemi Burkholder et al.,
Pseudomonas gladioli Severini and Enterobacter cloacae
(Jordan) Hormaeche and Edwards are specified as causing
soft rot of onion and garlic; however, these “are primarily a
problem on onions, but not garlic” (Davis et al. 2005).

NEMATODES

Ditylenchus dipsaci (Kühn) Filipjev is a major pest of Al-
lium spp. throughout temperate climes (Diekmann 1997;
Hannan and Sorensen 2002; Anon 2004). Hot water treat-
ment of soil and garlic; however, these “are primarily a
problem on onions, but not garlic” (Davis et al. 2005).

RESISTANT VARIETIES

Resistance and/or tolerance are other strategies. Although

TISSUE CULTURE: A PRACTICAL APPROACH
FOR SOME GROWERS

Garlic cloves are vegetative propagules with the conse-
quence that viruses persist in the next generation of garlic,
whether grown as seed stock or grown for the table. Most
seed garlic contains viruses, although not all are conspicu-
ously detrimental (Rosen et al. 2006). Chemical manage-
ment of multiple virus vectors (aphids, nematodes, thrips) is
difficult and expensive (e.g., Davis 1995), so alternative ma-

Tissue culture (usually meristem culture with one or two
leaf primordia) is a technologically viable method for gene-
rating virus-free garlic. Yields and profits from virus-free
cloves are demonstrably greater than for infected clones (Xu
et al. 2001). Sequential culture of meristem from shoot tips
is not always successful at eradication of viruses, but im-
proved techniques enhance success (Ayabe and Sumi 2001;
Pateña et al. 2005), including use of primordia of inflores-
cences and bulbils (Ebi et al. 2006). Analogous tissue culture
techniques have been used to free vegetatively propagated
Allium cepa var. ascalonicum (shallots) from virus infection
(Fletcher et al. 1998). Cryo-preservation of garlic is effec-
tive and such cryo-preserved stocks are often virus-free
(Keller et al. 2006), but effectiveness may vary with type
(hardneck versus softneck) and tissue (bulbils versus cloves)
(Volk et al. 2004).

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some reports are confined to possible resistance due to lack of viral symptoms or lack of detection of virus in certain cultivars (e.g., Pappu et al. 2006a; van Dijk 1993) other reports provide documentation on extensive testing for resistance to OYDV and LYSV in garlic (Lot et al. 2001).

There are also reports of resistance to fungi attacking garlic, e.g. Alternaria porri (Ellis) Cif. (Mehra and Batra 2005), Fusarium oxysporum f. sp. cepae (Rengwalska and Simon 1986), Penicillium hirsutum (Cavagnero et al. 2005), Pyrenochaeta terrestris (H.N. Hansen) Gorenz, J.C. Walker & Larson (Rengwalska and Simon 1986), Sclerotium cepivorum (Nabulsi et al. 2001), and Stemphylium vesicatorium (Wallr.) E. Simmons (Suheri and Price 2000). Red-skinned varieties of garlic tend to be more resistant to Embellisia alili than are white-skinned varieties, although some of the latter are also resistant (Dugan and Crowe, in press). However there are also reports of failure to locate resistance, e.g. for Penicillium hirsutum (Smalley and Hansen 1962), Puccinia allii F. Rudolph (Koike et al. 2001), and for S. cepivorum (Coley-Smith and Entwistle 1988). That results of some investigations are contrary to results of other investigations on the same pathogens serves only to emphasize the complexities and difficulties of locating resistance in germplasm.

GENETICALLY MODIFIED GARLIC

It is possible to transform garlic via particle bombardment (biolistic transformation) with plasmid DNA (McGraw 1998; Park et al. 2002; Sawahel 2002), with obvious implications for transfer of resistance genes. Mutation via gamma radiation has been reported as generating disease resistant mutants (Al Safadi et al. 2000).

CHALLENGES AND OUTLOOK

Garlic production is interesting from both horticultural and sociological perspectives because of the participation of many small growers and gardeners. Garlic fairs and festivals are held annually in several cities of North America, and garlic bulbs are often traded or sold for seed as well as consumed for pleasure. These practices also occur in the UK and in Europe. The Internet has provided many further outlets for sale or exchange amongst producers with limited financial resources but abundant enthusiasm and knowledge. Although there are numerous benefits to enhanced communication and germplasm exchange amongst these enthusiasts, there are also the dangers and consequences of spreading pathogens along with the germplasm. Although most pathogen species of garlic appear to be cosmopolitan, there is always the danger of introduction of pathogens or more aggressive pathogen genotypes into fields where they were previously absent.

Growers with greater financial resources are increasingly able to make use of tissue culture programs to generate disease-free planting stock, both for their own use and the market. One hopes that the formation of cooperatives or other mechanisms will allow the benefits of tissue culture to be shared with smaller producers. Refinements in diagnostic technology, especially affordable kits for virus detection, and the deployment of disease-resistance cultivars, should benefit large and small producers alike. It seems probable that genetically modified garlic with enhanced disease resistance or tolerance could also be beneficial, provided that such products are accepted in the market place.

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