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Storage Molds of Herbaceous Perennials[1]

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Abstract

Fungi were subcultured and identified to genera from 24 species of bare-root herbaceous perennials held in commercial cold storage chambers. Ten genera dominated the cultures. Although no pathogenicity tests were conducted, most genera were usually considered to be saprophytes or opportunistic pathogens which often infect previously damaged tissue. Other species of perrennials were harvested from commercial fields and given a Benlate dip fungicide treatment prior to storage. After six months, crowns were removed, rated for mold development, potted, and evaluated for quality of regrowth. Surface molds were generally suppressed by Benlate (Benomyl 50WP), but regrowth was rarely improved and often reduced. Use of fungicides to improve cosmetic appearance of stored herbaceous perennials is not recommended on the basis of these results.

Index Words: storage, mold, herbaceous perennial, benomyl, Benlate, fungicide

Significance to the Nursery Industry

Presence of surface molds on stored herbaceous perennials has been a cause for concern among nursery producers and their customers. On the basis of this research and the existing literature, we suggest that most of these superficial fungi are saprophytes or weak pathogens, growing primarily on material already dead or dying. Despite the prevalence of surface molds in storage, most may pose only a cosmetic problem. The unsightly appearence of fungal growth is best prevented by proper harvest and storage procedures rather than chemical treatments which add to production costs and can damage the plant material significantly. If necessary, fungicides should be used against internal pathogens causing soft rots such as oomycetes and bacteria which are more likely than surface molds to seriously decrease quality of stored herbaceous perennials.

Introduction

Surface storage molds are common on many horticultural products such as woody nursery stock (18), root crops (11), and strawberry crowns (1). The white or grey molds are often ephemeral, appearing and disappearing as material is transferred from one temperature or humidity to another. On stored bare-root perennials, surface molds detract from the appearance of the material and, to many nurserymen and consumers, suggest serious loss of subsequent regrowth quality. With the exception of bare-root strawberry plants, studies to identify pathogenic and nonpathogenic fungi on stored material are lacking. Although many genera of fungi have been isolated from both molded and healthy strawberry runners (5,13,20), pathogenicity studies have rarely shown that any actually cause disease in stored crowns (7,13).

Fungicide applications have at times been used effectively to reduce surface mold on stored strawberry crowns (1) and rose canes (18,21,22) as well as on carrots (3,15,23). However, a decrease in fungal growth does not necessarily result in an increase in plant vigor after planting (12). Some fungicides are toxic to herbaceous material (6). Currently, USDA recommendations suggest a pre-storage dip for woody rose canes but not for the herbaceous strawberry plants (8). Chemical control of surface molds on stored herbaceous perennials other than strawberry has received little attention.

This study was undertaken to provide preliminary identification of fungi present on a variety of stored herbaceous perennials and to examine the effect of pre-storage fungicide applications on plant regrowth after storage.

Methods and Materials

Chemical control. 1983 Experiments. Seven species of field-grown herbaceous perennials (*Gaillardia* X *grandiflora* Van Houtte, *Phlox subulata* L., *Alcea rosea* L., *Asparagus officinalis* L., *Lupinus* L. 'Russell Hybrids', *Coreopsis lanceolata* L., and *Dicentra spectabilis* (L.) Lem.) were harvested from commercial fields in Zeeland, MI, on November 18, 1983. The plants were commercially processed by removing loose soil and excess foliage. Pre-storage fungicide treatments, with 15 plants per treatment, were as follows: control (dry); water (10-minute dip); and Benlate (Benomyl 50WP) (10-minute dip at the recommended rate of 12 g/l). Wetted plants were held on open racks overnight at 20°C (68°F) to dry prior to packing.

After precooling at 2°C (36°F) for 24 hours, the plants were bulk packed in polythelene-lined crates and stored at −2°C (28°F) according to standard practice (10). They were removed from storage following 4 months for observation of surface mold development and returned to storage. After 6 months, the perennials were again removed and rated for mold development using a 1–5 scale (1 = no observable mold, 2 = 1–25% covered with mold, 3 = 26–50% coverage, 4 = 51–75% coverage, 5 = 76–100% coverage). The same plants were potted in a peat/perlite (1:1 by vol) mix and regrown in a cool (19°C D/13°C N; 67°F/55°F) green-

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house for 3 weeks, then evaluated for quality of regrowth on a 0–5 scale (0 = no observable growth, 1 = 1–20% of regrowth, 2 = 21–40% regrowth, 3 = 41–60% regrowth, 4 = 61–80% regrowth, 5 = 81–100% regrowth). In previous studies, treatment differences manifested in herbaceous perennials at 3 or 4 weeks after potting were indicative of future growth and development (9,19).

1984 Experiments. On November 11, 1984, another group of perennials was harvested and processed as in 1983. This group contained mostly plants stored with green foliage remaining (*Coreopsis grandiflora* Hogg ex Sweet, *Iberis sempervirens* L., *Lavandula angustifolia* Mill., *Teucrium chamaedrys* L., and *Dianthus deltoides* L.). The prestorage fungicide treatments given to 15 plants of each genus were as follows: control (dry); water (10-minute dip); Benlate (Benomyl 50WP) (10-minute dip at 6 g/l); Benlate (Benomyl 50WP) (10-minute dip at 12 g/l); and Benlate (Benomyl 50WP) (10-minute dip at 24 g/l). After 6 months, the plants were rated for mold development, then potted and rated after 3 weeks for regrowth quality as in 1983. Results of the chemical control experiments were statistically analyzed by species via ANOVA.

Fungal isolation and identification. On January 24, 1985, random samples of 24 species of bare-root herbaceous perennials (Table 1) with obvious surface mold were collected from a commercial cold storage. The plants had been harvested in late September or early October 1984, and held in bulk storage in loosely-closed polyethylene bags at 5°C (41°F). Whole plant samples were transferred to 5°C (41°F) storage in the laboratory for holding and were removed periodically throughout the next three months to isolate and identify associated fungi.

Fungi were subcultured from unwashed tissue, washed tissue, surface sterilized tissue (2% chlorine bleach solution for approximately 10-20 sec), or by direct transfer of mycelium from the plant surface. All available plant parts—root, crown, stem, and leaf—were sampled. Of the three culture media tried, potato-carrot agar (PCA) proved more suitable than potato-dextrose agar (PDA) or water agar (4). Fungi grew well on PCA, but not as rapidly as on PDA. Cultures were incubated at 20°C (68°F) and inspected weekly for fungal growth. Secondary transfers were made when necessary to isolate a particular colony. Most fungi were identified on the basis of morphology to genus under a light microscope. Oomycetes were identified only to class since they did not sporulate under the cultural conditions provided and could not be separated on the basis of mycelial morphology. Some cultures did not develop identifiable structures and were not classified.

Results and Discussion

Fungi were readily cultured from all the perennials and all plant parts examined. Ten genera dominated the cultures, and often as many as five genera were isolated from the same plant (Table 1). Montgomerie (20) reported finding up to four genera per strawberry crown. There was no clear

Table 1. Fungi identified in cultures from bare-root herbaceous perennials during storage. Plants were field-harvested in the fall and held at 5°C (41°F) until sampled.

Genus and Storage Type	Species/CV	Penicillium	Rhizopus/Mucor	Alternaria	Fusarium	Botrytis	Rhizoctonia	Other Genera	Class Oomycetes
Taproot									
Alcea	rosea	r	r						
Aquilegia	'Dragon Fly'	c	r,l	r					
Lunaria	biennis	l	r,l	r	r				
Lupinus	'Russell Hybrid'	c,r	r,c	r	r			r-Papulospora	
Papaver	orientale	r					c		r,c
Fibrous Root									
Chrysanthemum	X morifolium		s	r,s	r,c	r,s			
Eupatorium	coelestinum	r	r	r	r	r		r-Papulospora	
Helianthus	multiflorus	r	r	r,s	r,s		c		
Monarda	didyma	l,r	r	l,s,r			r,s	l-Echinobotrium	s
Physostegia	virginiana	r				r			l
Veronica	'Pavane'	c	r,c	r,l,c	r,c	c	c		l
Fleshy Rootstock									
Dicentra	eximia	r	r	r,l,c	l,c			c-Echinobotrium	l.r
Hosta	'Royal Standard'	c,r	r,c	r	r	r		r-Papulospora	r
Phlox	paniculata		c		r			r-Papulospora	r,s,c
Green Top									
Iberis	sempervirens	l		r,l					r
Phlox	subulata	r,l		l	r,l,c				
Sedum						l,s		r-Cylindrocarpon	
Rhizome									
Iris	germanica	c	c		c,r	c			r
Iris	pumila	l		r,l	l			l-Echinobotrium	l-Plasmopara
Oenothera	missouriensis					r		r-Papulospora	
Tradescantia	X andersoniana	r,l	r,l	l	l,r				l,r
Woody Rootstock									
Astilbe	X arendsii								r,c
Brunnera	macrophylla	r	r			r	r		r
Liatris	spicata							c-Cylindrocarpon	l,r

KEY: r = root, c = crown, l = leaf, s = stem as source of culture

Table 2. Effect of differing concentrations of Benlate on mold development and regrowth quality of stored herbaceous perennials. Plants were field-harvested in the fall and held in polyethylene-lined crates at −2°C (28°F) for 6 months.

Cultivar Name		Mold Ratings[z]					Regrowth Ratings[y]				
		Control	Water	Benlate 6mg/l	Benlate 12mg/l	Benlate 24mg/l	Control	Water	Benlate 6mg/l	Benlate 12mg/l	Benlate 24mg/l
1983 Experiments											
Alcea	rosea	2.0	2.0	—	1.0x	—	2.3	3.1	—	4.0x	—
Asparagus	officinalis	2.0	1.7	—	1.3x	—	3.0	2.3	—	2.9	—
Coreopsis	lanceolata	3.3	3.1	—	1.3x	—	1.8	1.2	—	3.7x	—
Dicentra	spectabilis	3.4	2.8x	—	2.7x	—	2.5	2.9	—	2.1	—
Gaillardia	X grandiflora	2.1	1.3x	—	1.0x	—	3.1	3.5	—	3.1	—
Lupinus	'Russell Hybrid'	1.9	2.1	—	1.1x	—	1.9	2.1	—	3.3x	—
Phlox	subulata	1.6	1.5	—	1.5	—	3.9	4.0	—	4.3	—
1984 Experiments											
Coreopsis	grandiflora	3.3	3.3	2.2x	1.7x	1.4x	3.1	3.0	2.5	1.5x	1.0x
Dianthus	deltoides	1.1	1.1	1.0	1.0	1.0	4.0	3.7	3.3	2.6x	1.4x
Iberis	sempervirens	1.5	1.8	1.4	1.1x	1.1x	4.1	3.3	1.0x	0.9x	0.3x
Lavendula	angustifolia	2.3	2.3	1.1x	1.1x	1.0x	2.6	2.5	3.4	0.3x	0.1x
Santolina	incana	3.4	2.1x	1.1x	1.1x	1.0x	0.0	0.0	0.0	0.0	0.0
Teucrium	chamaedrys	1.7	1.3x	1.0x	1.0x	1.0x	4.7	4.9	4.8	3.9x	2.3x

[z]1 to 5 scale for 0 to 100% covered by surface mold.

[y]0 to 5 scale for 0 to 100% attainment of expected regrowth after 3 weeks in greenhouse.

[x]significantly different from the control at the 5% level as determined by LSD test.

pattern relating certain genera of fungi to specific plants, plant parts, isolation techniques, or plant storage types. Visible molds almost always occurred only on cut or bruised tissue and on dead plant parts. Many of the fungi in Table 1 have been isolated from strawberry (1). As Gourley (5) observed on strawberry, most of the fungi were genera such as *Rhizopus* and *Penicillium*, most often considered saprophytes or opportunistic pathogens, causing secondary infections on already damaged tissue. However, in this study we did not identify fungi to species nor did we conduct pathogenicity studies; therefore, the virulence of the fungi we observed remains unknown. Oomycetes were also associated with the perennials in great numbers. This class of fungi contains genera such as *Pythium, Phytophthora*, and *Aphanomyces* which can cause serious diseases including soft rot. The role of oomycetes in storage diseases of perennials should be examined further.

Surface molds were controlled by applying fungicide just prior to storage in both 1983 and 1984 (Table 2). Benlate decreased the extent of mold growth significantly on all but two species (*Phlox subulata* and *Dianthus deltoides*) which had very little mold on controls. However, regrowth was rarely improved by treatment (Table 2). In fact, plant quality was often decreased by use of fungicides. Two other fungicides, Captan and Rovral (iprodione), were used in preliminary tests with similar results (data not shown). Perennials stored with green tops were particularly susceptible to injury by higher concentrations of Benlate. *Alcea* and *Lupinus*, both stored as carrot-like taproots without leaves or green crown, were the only plants that seemed to genuinely benefit in regrowth quality by fungicide application. Derbyshire and Crisp (3) found that benomyl reduced rotting of stored carrots from about 40% to about 5%. Carrot is particularly susceptible to infection through flesh wounds on machine-harvested roots (11). *Coreopsis lanceolata* also showed reduced mold development and improved regrowth after treatment with Benlate, but *C. grandiflora*, a very closely related species, was damaged by the fungicide. Such conflicting results cast doubt on the reliability of fungicidal treatments. Based on these findings, we cannot recommend broad use of fungicides in the control of storage molds on herbaceous perennials.

In our experience, mold development is minimal during storage of most species of herbaceous perennials when storage conditions are optimized (14, 16, 17; Cameron, unpubl. observations). Stresses to the bare-root plants such as extensive wounding, desiccation, presence of free water, early season harvest, and wide or frequent temperature changes during storage interfere with the plant's natural ability to resist invasion by opportunistic parasites and therefore favor growth of fungi already present on the plant (1, 2, 14, 16; Hanchek, unpubl. observations). In such cases, fungal growth may act as an indicator of poor quality material, rather than the cause of it. However, growers invariably associate the presence of surface molds with loss of quality in a cause-and-effect process. Yet little relationship existed between surface mold development and regrowth quality of herbaceous perennials in this and several other studies (9, 12, 19). Spores appear to be ubiquitous during storage since fungi were easily obtained from plant material with no obvious mold development. Similarly, the same genera of fungi present on molded strawberry crowns were found on non-molded plants (5, 13, 20). Control of saprophytes by fungicides would thus improve only the immediate appearance of the plant and not necessarily the regrowth response.

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Chilling Units Used to Determine Rooting of Stem Cuttings of Junipers[1]

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Abstract

Stem cuttings from 10 juniper cultivars, representing 5 taxa of juniper (*Juniperus chinensis* L. 'Pfitzer Aurea'; *J. horizontalis* Moench 'Bar Harbor', 'Prince of Wales', 'Wiltoni', 'Youngstown'; *J. procumbens* Endl. 'Green Mound'; *J. sabina* L. 'Broadmoor', 'Buffalo', 'Tamariscifolia' and; *J. scopulorium* Sarg. 'Wichita Blue') were inserted into rooting beds twice monthly from October 15, 1986 to February 28, 1987. During this time period, air temperature was monitored continuously 1 m (39 in) above the stock plants and seasonal chilling units (i.e., hours at ≤5°C (41°F)) were determined. Chilling units of the donor stock plants affected the percent rooting of most juniper cultivars. Data suggest that the optimum rooting period of most cultivars of juniper can be determined by their chilling units.

Index words: vegetative propagation, degree hour chilling sum

Species used in this study:

Pfitzer Aurea (*Juniperus chinensis* L.); Bar Harbor, Prince of Wales, Wiltoni, Youngstown (*J. horizontalis* Moench); Green Mound (*J. procumbens* Endl.); Broadmoor, Buffalo, Tamariscifolia (J. sabina L.); Wichita Blue (*J. scopulorium* Sarg.)

Significance to the Nursery Industry

Most junipers produced by the nursery industry are propagated via stem cuttings and each cultivar has a different inherent rooting capability. Thus, knowing when to take cuttings from stock plants can be critical for rooting success. As the environmental conditions change throughout the year, so does the physiological status of stock plants which in turn influences the rooting capacity of cuttings taken from these plants. The chilling unit concept (i.e. the number of hours that air temperature is below some limit known to be effective) may help determine the optimum time to take cuttings from stock plants.

Introduction

Successful propagation of woody plants by stem cuttings is influenced by many cultural, physiological and environmental factors. Time of year has been reported to be im-

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