CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

California Pest Rating Proposal for

Rhizopus stolonifer (Ehrenb.: Fr.) Vuill. 1902

Bulb rot

Current Pest Rating: C

Proposed Pest Rating: C

Kingdom: Fungi; Phylum: Mucoromycota

Subphylum: Mucoromycotina; Order: Mucorales

Family: Mucoraceae

Comment Period: 09/29/2020 through 11/13/2020

Initiating Event:

On August 9, 2019, USDA-APHIS published a list of "Native and Naturalized Plant Pests Permitted by Regulation". Interstate movement of these plant pests is no longer federally regulated within the 48 contiguous United States. There are 49 plant pathogens (bacteria, fungi, viruses, and nematodes) on this list. California may choose to continue to regulate movement of some or all these pathogens into and within the state. In order to assess the needs and potential requirements to issue a state permit, a formal risk analysis for *Rhizopus stolonifer* is given herein and a permanent pest rating is proposed.

History & Status:

Background: Zygomycete fungi that reproduce sexually with zygospores were once all classified in the phylum Zygomycota. Zygomycetes are filamentous, nonflagellated fungi that mark an important evolutionary step from the earliest zoosporic fungi toward the nonflagellated, filamentous, multicellular dikarya. However, more recent analyses of molecular phylogenies have not supported the taxonomic structure, and Zygomycota has been abandoned in preference for the phylum Mucoromycota. The zygomycetes were moved into four subphyla incertae sedis. The subphylum Mucoromycotina now holds mycorrhizal fungi, root endophytes, and both pathogens and decomposers of plant material including the important genera *Mucor* and *Rhizopus* (Hibbitt et al., 2007; Spatafora et al., 2016).

Zygomycetes are strictly terrestrial fungi and their spores are often found in the air. They can be either saprophytes or weak parasites of plants and plant products, causing soft rots or molds. Some, including *Rhizopus* spp., are also opportunistic pathogens of humans and animals. Zygomycetes have well-developed mycelia without cross walls and produce spores in sporangia; their sexual resting spore is a thick-walled zygospore produced by the union of two morphologically similar gametes (Spatafora et al., 2016).

Rhizopus stolonifer is a common bread mold fungus, and it causes soft rot of many fleshy fruits, vegetables, flowers, bulbs, corms, and seeds. *Rhizopus stolonifer* is a weak parasite, but it can grow and fruit prolifically on dead or processed plant products. The pectinolytic enzymes secreted by *R. stolonifer* advance ahead of its mycelium and separate the plant cells. Next it produces cellulolytic enzymes that break down the cellulose of the cell wall and the cells disintegrate, allowing the contents to leak out. The mycelium does not always invade host cells but can instead surround itself with dying, dead, and dissolving plant cells, thus behaving more like a saprophyte than a parasite (Agrios, 2005).

Hosts: There are hundreds of described hosts in dozens of plant families including vegetables, ornamentals, fruits, bulbs, seeds, nuts, and grains (Farr and Rossman, 2020; French, 1989).

Symptoms: Infected areas of fleshy fruit such as peaches and pears will first appear water soaked and become very soft. If the skin of the fruit remains intact, it loses moisture gradually and it shrivels. Alternately, fungal hyphae will break through the skin and grow outward and cover the affected portions by producing tufts of whisker-like white or gray mycelium and sporangiophores with prominent black sporangia. The fungal growth will spread over the surface of the healthy portions of affected fruits and even to the fruit containers as they become wet with the exuding juices. Affected tissues at first give off a mildly pleasant smell, but soon yeasts and bacteria colonize, and the smell becomes sour. When loss of moisture is rapid, infected fruits dry up and mummify (Agrios, 2005).

Hull rot of almond is caused by *R. stolonifer* producing gray to brown lesions on the mesocarp of maturing almond fruits. This leads to necrosis and death of leaves and part or all the attached spurs or shoots. The fungus will sporulate profusely in between the hull and the shell (Teviotdale et al., 1996).

Disease on strawberry fruit caused by *R. stolonifer* is called “leak”. Initially, infections appear as discolored, water-soaked spots. These spots enlarge rapidly, aided by enzymatic breakdown that causes the berry to become limp, brown, and leak out its contents. Under conditions of high relative humidity, it becomes covered with a coat of white mycelium and sporangiophores. The sporangiophores develop black, spherical sporangia, each containing thousands of spores. When touched, these sporulating berries release a cloud containing millions of spores (Koike et al., 2018).

On sugarbeet, *R. stolonifer* causes root rot. The first symptoms are a temporary wilting of foliage during periods of moisture stress; but as the root rot advances, wilting is permanent. After the roots are killed, the foliage becomes very brittle and dry. Rotted roots appear dark grayish brown and spongy, with darker vascular rings. The taproot can eventually be completely consumed and replaced

with white mycelium. Black sporangia follow. Often the fungus will decay the internal tissues of the beet creating a cavity filled with a clear fluid that smells like acetic acid (Kaffka et al., 2005).

Transmission: Before infecting living plant tissues, *R. stolonifer* first colonizes and grows on injured or dead plant parts in order to build up large masses of mycelia. The mycelia secrete enzymes that diffuse into the living tissue and disrupt and kill the cells. The mycelium of *R. stolonifer* produces stolons, hyphae that arch over the surface to find distant points of contact. It also produces root-like hyphae called rhizoids, which grow down into the substrate. The mycelium produces long, aerial sporangiophores that produce black, spherical sporangia at their tips. The sporangia contain thousands of sporangiospores. The terminal mycelial cells are the gametangia that fuse so their nuclei sexually pair. The cell formed by the fusion is called a zygospore, and it enlarges and develops a thick, black, and warty cell wall. The zygospore is also the overwintering or resting stage of the fungus. When it germinates it produces a sporangiophore bearing a sporangium full of sporangiospores. Zygospores help the fungus survive periods of starvation and adverse temperature and moisture levels (Agrios, 2005). The sporangiospores are released very easily by any physical disruption or by strong air currents, rain, or overhead irrigation. Infected fruits often drop and the *R. stolonifer* will continue to sporulate profusely, providing a large source of inoculum.

Damage Potential: Rhizopus stolonifer occurs throughout the world on a huge range of crops during storage, transit, and marketing. Among the crops most severely affected most by this disease are sweet potatoes, strawberries, cucurbits, peaches, cherries, and peanuts. Corn and some other cereals are affected under high moisture. Bulbs, corms, and rhizomes of flower crops are also susceptible to this disease. When conditions are favorable, the disease spreads rapidly throughout the containers, and losses can be great or even total in a short period of time (Agrios 2005).

Worldwide Distribution: Cosmopolitan and distributed worldwide.

Official Control: None

California Distribution: Widespread as a saprophyte and weak pathogen.

California Interceptions: None

The risk *Rhizopus stolonifer* would pose to California is evaluated below.

Consequences of Introduction:

1) **Climate/Host Interaction:** *Rhizopus stolonifer* is ubiquitous in subtropical and temperate climates throughout California.

Evaluate if the pest would have suitable hosts and climate to establish in California.

Score: **3**

- Low (1) Not likely to establish in California; or likely to establish in very limited areas.

- Medium (2) may be able to establish in a larger but limited part of California.
- High (3) likely to establish a widespread distribution in California.

2) **Known Pest Host Range:** The host range is extremely large with hundreds of susceptible species and multiple plant parts affected.

Evaluate the host range of the pest.

Score: 3

- Low (1) has a very limited host range.
- Medium (2) has a moderate host range.
- High (3) has a wide host range.

3) **Pest Reproductive Potential:** *Rhizopus stolonifer* reproduces with asexual and sexual spores, and with prolific mycelium that can grow between plants or fruit, and on the containers, boxes and trays holding fruit. Spores are spread easily with air currents.

Evaluate the natural and artificial dispersal potential of the pest.

Score: 3

- Low (1) does not have high reproductive or dispersal potential.
- Medium (2) has either high reproductive or dispersal potential.
- High (3) has both high reproduction and dispersal potential.

4) **Economic Impact:** *Rhizopus stolonifer* causes economically significant pre- and postharvest diseases, notably on almond, sugarbeet, and strawberry in California.

Evaluate the economic impact of the pest to California using the criteria below.

Economic Impact**: A, B**

A. The pest could lower crop yield.
B. The pest could lower crop value (includes increasing crop production costs).
C. The pest could trigger the loss of markets (includes quarantines).
D. The pest could negatively change normal cultural practices.
E. The pest can vector, or is vectored, by another pestiferous organism.
F. The organism is injurious or poisonous to agriculturally important animals.
G. The organism can interfere with the delivery or supply of water for agricultural uses.

Economic Impact Score: **2**

- Low (1) causes 0 or 1 of these impacts.
- Medium (2) causes 2 of these impacts.
- High (3) causes 3 or more of these impacts.

5) **Environmental Impact:** Cultural practices including field or orchard sanitation of fallen fruit and careful handling and rapid cooling are implemented to reduce the spread of *R. stolonifera*.

Environmental Impact: E

A. The pest could have a significant environmental impact such as lowering biodiversity, disrupting natural communities, or changing ecosystem processes.
B. The pest could directly affect threatened or endangered species.
C. The pest could impact threatened or endangered species by disrupting critical habitats.
D. The pest could trigger additional official or private treatment programs.
E. The pest significantly impacts cultural practices, home/urban gardening or ornamental plantings.

Environmental Impact Score: 2

- Low (1) causes none of the above to occur.
- Medium (2) causes one of the above to occur.
- High (3) causes two or more of the above to occur.

Consequences of Introduction to California for *Rhizopus stolonifer:* High

Add up the total score and include it here. **13**
-Low = 5-8 points
-Medium = 9-12 points
-High = 13-15 points

6) **Post Entry Distribution and Survey Information**: Evaluate the known distribution in California. Only official records identified by a taxonomic expert and supported by voucher specimens deposited in natural history collections should be considered. Pest incursions that have been eradicated, are under eradication, or have been delimited with no further detections should not be included.

Rhizopus stolonifer is ubiquitous in agricultural areas, associated with soil, decaying plant material, and living hosts pre- and postharvest.

Evaluation is 'high'.

Score: -3
-Not established (0) Pest never detected in California or known only from incursions.
-Low (-1) Pest has a localized distribution in California or is established in one suitable climate/host area (region).
-Medium (-2) Pest is widespread in California but not fully established in the endangered area, or pest established in two contiguous suitable climate/host areas.
-High (-3) Pest has fully established in the endangered area, or pest is reported in more than two contiguous or non-contiguous suitable climate/host areas.

7) **The final score is** the consequences of introduction score minus the post entry distribution and survey information score: (Score)

Final Score: *Score of Consequences of Introduction – Score of Post Entry Distribution and Survey Information* **= 10**

Uncertainty:

None

Conclusion and Rating Justification:

Based on the evidence provided above the proposed rating for *Rhizopus stolonifer is C*.

References:

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Koike, S.T., Browne, G.T., Gordon, T.R., and Bolda, M. P. 2018. Strawberry Pest Management GuidelinesRhizopus Fruit Rot (LEAK) UC IPM Pest Management Guidelines: Strawberry UC ANR Publication 3468

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Responsible Party:

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***Comment Period: 09/29/2020 through 11/13/2020**

***NOTE:**

You must be registered and logged in to post a comment. If you have registered and have not received the registration confirmation, please contact us at permits[@]cdfa.ca.gov.

Comment Format:

- Comments should refer to the appropriate California Pest Rating Proposal Form subsection(s) being commented on, as shown below.

  Example Comment:

  Consequences of Introduction: 1. Climate/Host Interaction: [Your comment that relates to "Climate/Host Interaction" here.]

- Posted comments will not be able to be viewed immediately.
- Comments may not be posted if they:

  Contain inappropriate language which is not germane to the pest rating proposal;

  Contains defamatory, false, inaccurate, abusive, obscene, pornographic, sexually oriented, threatening, racially offensive, discriminatory or illegal material;

  Violates agency regulations prohibiting sexual harassment or other forms of discrimination;

  Violates agency regulations prohibiting workplace violence, including threats.

- Comments may be edited prior to posting to ensure they are entirely germane.
- Posted comments shall be those which have been approved in content and posted to the website to be viewed, not just submitted.

Proposed Pest Rating: C
