Research Note

FRUITY AROMAS FROM PINK MOLD AND THEIR ASSOCIATION WITH INSECT ATTRACTION[1]

Besides visual stimuli, odors are important insect attractants. Fruity smelling esters are attractive to fruit flies and beetles, particularly sap beetles.[2] Members of the fungal genus *Ceratocystis* are well known for their production of fruity smelling volatiles.[3, 4] The fruity aromas of the oak wilt fungus (*Ceratocystis fagacearum*) attract fruit flies, sap beetles and a variety of other animals, including squirrels which feed on the fungus and transmit it to healthy trees.[5]

Besides *C. fagacearum*, *C. paradoxa* is known for its sweet fruity aroma.[6] This fungus causes soft rots in a variety of tropical plants. Rotting sugar cane seedpieces, tropical fruits and tubers take on a smell of overripe pineapples. The volatiles from the so-called "pineapple" rots chemically suppress seed-piece sprouting and can easily be detected in soil surrounding decaying seedpieces.[7] Sap beetles are important vectors of pineapple disease of sugarcane and other tropical crops and benefit from this fungus *in their diet*.[8] *A clear symbiosis exists* between the insect vector and the transmitted fungus.

Tree pathologists place diagnostic significance on the production of fruity aromas. In laboratory cultures of diseased oak twigs, check for the oak wilt fungus is not made until a preliminary olfactory examination yields a smell of "apples" or "bananas." Presence of this fruity smell distinguishes the oak wilt from the Dutch elm fungus (personal observation, Paul R. Hepperly). Fruity aroma has also been used to indicate strains within *Fusarium oxysporum*.[9]

Insects can be important aids to the cross fertilization of heterothallic fungi. Rust pycnia are attractive to flies that aid spermatization.[10, 11] Beetles are important in the cross fertilization of the oak wilt and

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Dutch elm fungi which are also heterothallic.[12, 13, 14]

Fruity aromas, thus, play roles of importance in the reproduction and dispersal of pathogenic fungi and in pathogenesis and pathogen taxonomy.

Corn (*Zea mays* L.) and sorghum [*Sorghum bicolor* (L.) Moench] are seriously damaged by pink mold. The causal fungus, *Fusarium moniliforme* Sheldon, attacks their roots, stalks, panicles, and seeds.[15] Although the pathogen is found throughout the world, the disease is most damaging in semitropical and tropical zones.

Soil-borne inoculum is usually considered of prime importance in diseases caused by *Fusarium*.[16] Pink mold is usually described as air-, soil-, and seed-borne.[17] In Minnesota, soilborne inoculum was not detected in corn field soil where plants showed pink mold symptoms.[18] In Israel, *F. moniliforme* constituted less than 5% of the total soil-borne population of *Fusarium*.[19]

Whereas the soilborne nature of pink mold is easily overestimated, insect transmission is not usually considered. An early classic demonstration of transmission of fungal diseases by insects was that of pollinating fig wasps carrying *F. moniliforme*, which causes fig endosepsis.[20] Internal infections of *F. moniliforme* were found in picnic beetles which were feeding on corn silks.[21] High levels of seed infection are found in corn.[22] Internal infections of insects were found in corn earworm and sugar cane borers.[23] Elucidating possible symbiotic relationships between *F. moniliforme* and several insects merits further study.

Besides corn, pink mold has been associated with insect activity in cotton and sorghum. Boll rot by *F. moniliforme* increases with increased insect activity.[24] In sorghum, insects increase stalk rot[25] and insect control reduces pink molds but not black seed mold.[26]

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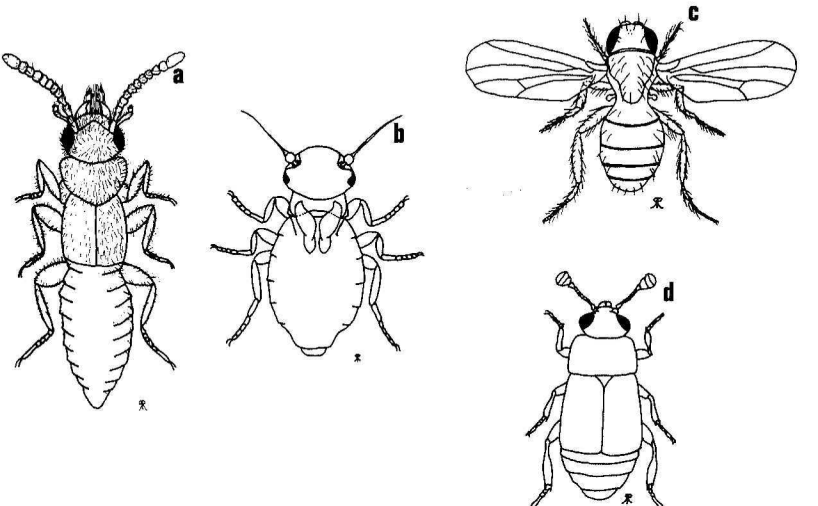

FIG. 1.—Insects discovered on maize (*Zea mays* L.) seed with pink mold *Fusarium moniliforme* Sheldon) during trapping experiments. A) Coleoptera: Staphynilidae, rove beetles; B) Psocoptera, book lice, as found in the greenhouse; C) Diptera: Drosophilidae, fruit flies; and D) Coleoptera: Nitidulidae, sap beetles, as found in field tests.

Just as some plant pollens have adapted for insect dispersal based on their scent, taste, and physical constitution, insect-transmitted fungi show adaptation to insect dispersal.[27] The slimy sweet-smelling sticky masses of the pink mold fungus are well adapted to insect dispersal.[28] The large dry solitary spores of black molds lack adaptation to insect adherence and dispersal.

When grown on sterilized corn kernels at 27° C, pure cultures of *F. moniliforme* produced strong fruity aromas noticeable 10 to 14 days after first report of fruity volatiles from this fungus. The production of the fruity aromas coincided with conidia production. Volatiles were not noted in the mycelial stages.

Culture flasks (1 L capacity) were filled with 200 ml of dry corn kernels or with *F. moniliforme* cultures. These were opened for greenhouse and laboratory testing. Pink mold cultures on corn attracted over 30 individuals of the order Psocoptera, whereas dry corn seed did not attract any. The psocids, commonly known as book or bark lice, feed on molds.[29] Fewer than 5 rove beetles (Staphylinidae) were found on pink mold and none on dry kernels. Rove beetles usually frequent fungal litters as insect predators. In the field, sap beetles (Nitidulidae) and fruit flies (Drosophilidae) were found on pink mold. No sap beetles were found on dry seed but a lesser number of fruit flies were found in the control. Yeasts are an important food for fruit fly larvae.[29] Both sap beetles and fruit flies frequent flowers as pollen and nectar feeders.[29] The attraction of these insects to both flowers and fruits and fungi increases the probability of insect- and seed-transmission of pathogenic and non-pathogenic molds. Figure 1 presents the drawing of the insects we found associated with pink mold.

We believe that present day description of pink mold on corn and sorghum underestimates the role of insects in disease transmission. Fruity aroma appears to be evidence for *F. moniliforme* adaptation to insect dispersal. Sticky conidial masses and raised phialides also suggest this adaptation. Among the Fusaria, fruity aromas were previously only reported for certain strains of *F. oxysporum*. Production of fruity aromas by *F. moniliforme* as well as *F. oxysporum* may indicate the close relationship of these species. Close affinity of *F. moniliforme* and *F. oxysporum* has long been suspected by *Fusarium* taxonomists.[30]

Paul R. Hepperly
Tropical Agriculture Research Station, USDA-ARS
Roberto E. Rodriguez-Cancel
Department of Crop Protection

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