Colonization of Delicious Apple Fruits by *Alternaria* spp. and Effect of Fungicide Sprays on Moldy-Core

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ABSTRACT

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Fourteen genera of fungi were isolated from the core region of Delicious apple fruits. *Alternaria* spp. were the most commonly isolated fungi. *Alternaria* spp. colonized flower parts during and shortly after bloom and later moved (presumably through the open calyx tube) into the receptacle or core region of the fruit. During 2 yr of testing in Ohio, *Alternaria* was recovered from the core region of almost 100% of all Delicious fruits tested at harvest. The mean percentage of fruit with moldy-core (visible mycelia in the core region at harvest) was 38 and 65% in 1980 and 1981, respectively. A variety of fungicide spray programs had no effect on the rate of flower and fruit colonization by *Alternaria* spp. or on the incidence of moldy-core at harvest.

Under conditions of high relative humidity and mild temperatures during late spring, many fungi can infect the fruit of open-calyx apple cultivars like Delicious (4,5). These fungi enter the calyx and colonize the core or carpel area, resulting in a condition known as moldy-core. Once inside the fruit, the fungi are protected against contact with fungicides, and conditions for their growth are excellent. Fruits with moldy-core have a black to gray fungus growth over the seed and carpel walls (Figs. 1 and 2). The entire central portion of the core may often be filled with mycelium. Occasionally, fungal colonization extends from the carpels into the outside flesh and appears externally as a brown rot, but rotting of the flesh is not common (1,3). Disease incidence has been reported to be greater in apples that have been damaged by late spring frost so that seeds do not develop normally (4).

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Ellis (3) reported that 98% of the fungi isolated from the cores of several open-calyx apple cultivars were *Alternaria* spp. *A. alternata* was the most prevalent species. *Alternaria* spp. were recovered from 426 of 500 cores (either seed or carpel wall) tested, and the infection had spread beyond the carpel wall in only two fruits.

Ohio growers have experienced high levels of moldy-core in Delicious during the 1979, 1980, and 1981 growing seasons. Affected fruits appeared normal when harvested and sold, but when cut in half, fungus growth was observed in the core and many consumers assumed that the fruit was rotten. In addition, at least one commercial processing company in Ohio will not buy Delicious fruit with more than 6% moldy-core. Therefore, moldy-core is a factor that reduces apple fruit quality and can become an

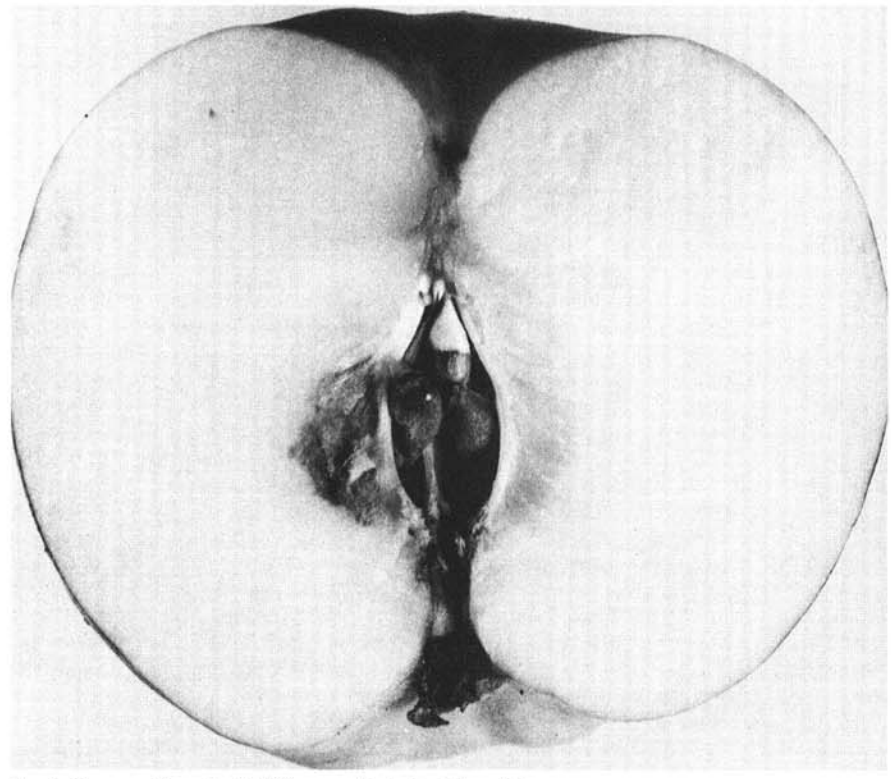

Fig. 1. Cross section of a Delicious apple fruit with moldy-core.

economically important problem. These investigations were conducted to determine when *Alternaria* spp. invade the fruit of Delicious and what effect fungicide sprays have on disease incidence.

MATERIALS AND METHODS

In 1980, the following fungicides and fungicide combinations (rates in active ingredients) were applied to 11-yr-old Delicious trees on MM·106 rootstock at Wooster, OH: benomyl 50WP, 0.42 kg/ha (6 oz/acre), plus captan 50WP, 4.49 kg/ha (4 lb/acre); benomyl, 0.42 kg/ha, plus mancozeb 80WP, 7.18 kg/ha (6.4 lb/acre); dodine 65P, 0.27 kg/ha (3.9 oz/acre), half-inch green through first cover, followed by captan, 4.49 kg/ha; and dikar 80WP, 7.18 kg/ha. Application dates and growth stages for 1980 were: 22 April (half-inch green), 29 April (tight cluster); 6 May (pink), 14 May (bloom), 21 May (petal fall), 30 May (first cover), 13 June (second cover), 19 June (third cover), 3 July (fourth cover), 17 July (fifth cover), 25 July (sixth cover), 4 August (seventh cover), and 18 August (eighth cover). Unsprayed trees served as controls. Treatments were applied to four two-tree replicates in a complete randomized block design. Trees were sprayed to runoff (3,740 L/ha [400 gal/acre]) at 3,100 kPa (450 psi) with a handgun.

Flowers and fruits were collected from all treatments to determine when *Alternaria* moved into fruit. Flowers were collected on 16 May in the following stages of development: bud not open, petals half open, and petals fully open. Ten flowers were collected from each replicate per treatment and stage of development. All samples were cut in cross section to separate the flower parts from the receptacle. Flower parts and receptacles were surface-disinfested by soaking in 0.25% NaOCl for 1.5 min then in sterile distilled water for 1 min. Flower parts and receptacles were plated separately on potato-dextrose agar (PDA) in sterile petri dishes. Plates were incubated 7–10 days at 24 C and the incidence of fungi was recorded. Samples of fruit at different stages of development were collected on the following dates: 22 May (petal fall), 20 June, 14 August, and 22 September. The peduncle (stem) and calyx ends were removed from all fruits with a scalpel or knife. The remaining portion of the fruit was sliced longitudinally to remove all portions external to the core region. The remaining core region and calyx end of each fruit were surface-disinfested as previously described and plated separately on PDA. Plates were incubated at 24 C for 7–10 days and the incidence of fungi was recorded.

On 22 September, 100 fruits per replicate and fungicide treatment were cut in half longitudinally and the incidence of moldy-core (visible mycelia in the core region) at harvest was recorded.

In 1981, the experiment was repeated as previously described using the following fungicides and fungicide combinations (rates in a.i.): benomyl, 0.42 kg/ha, plus CGA-64251, 0.06 kg/ha (8 oz/acre); benomyl, 0.42 kg/ha plus bitertanol, 0.28 kg/ha (4 oz/acre); benomyl, 0.28 kg/ha plus mancozeb, 7.18 kg/ha; and mancozeb, 7.18 kg/ha. Application dates for 1981 were: 13 April (half-inch green), 16 April (half-inch green repeated because of rain), 23 April (tight cluster), 1 May (pink), 8 May (bloom), 15 May (petal fall), 22 May (first cover), 29 May (second cover), 8 June (third cover), 22 June (fourth cover), 8 July (fifth cover), 23 July (sixth cover), 13 August (seventh cover), and 2 September (eighth cover). Unsprayed trees served as controls.

Flowers were collected at different stages of development on 9 May and treated as previously described. Samples of fruit were collected at different stages of development and treated as previously described on the following dates: 15 May (petal fall), 17 May (2 days after petal fall spray), 3 and 30 June, 26 August, and 14 September. On 14 September, 100 fruits per replicate and treatment were cut in half longitudinally and the incidence of moldy-core at harvest was recorded.

RESULTS AND DISCUSSION

The following genera of fungi were isolated from the core region of Delicious apple fruits in this study: *Alternaria, Botrytis, Candida, Cladosporium, Coniothyrium, Fusarium, Aspergillus, Gloeosporium, Epicoccum, Penicillium, Pestalotia, Phoma, Sporathrix, Trichoderma,* and *Rhizopus*. These fungi were isolated from inside apparently healthy fruit, which indicates that the open calyx tube of Delicious provides an excellent entry for a broad range of fungi. *Alternaria* spp. were by far the most commonly isolated fungi. Visible mycelia

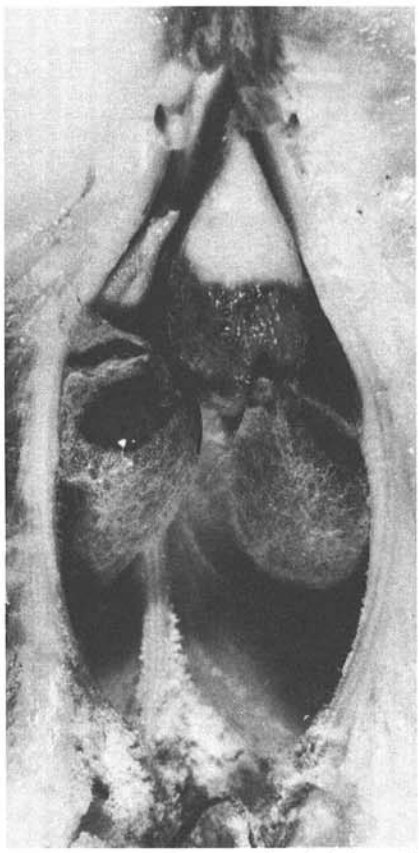

Fig. 2. Close-up of core region in Figure 1. Note the mycelia on the surface of seeds and within the carpel chambers (locules).

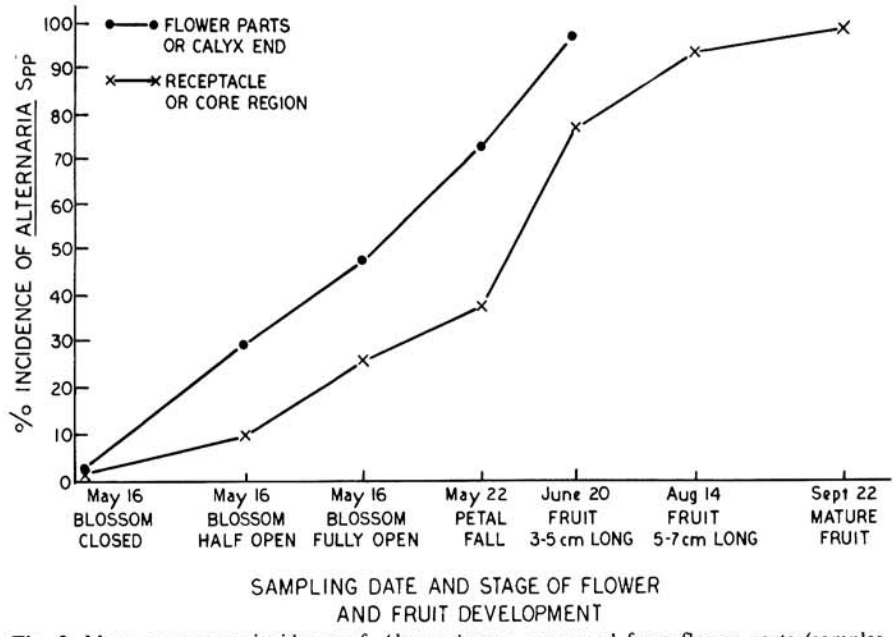

Fig. 3. Mean percentage incidence of *Alternaria* spp. recovered from flower parts (samples collected before 20 June) or calyx ends (samples collected after 22 May) and respective receptacles (collected before 20 June) or core regions (collected after 22 May) of Delicious fruits collected at various stages of development in 1980.

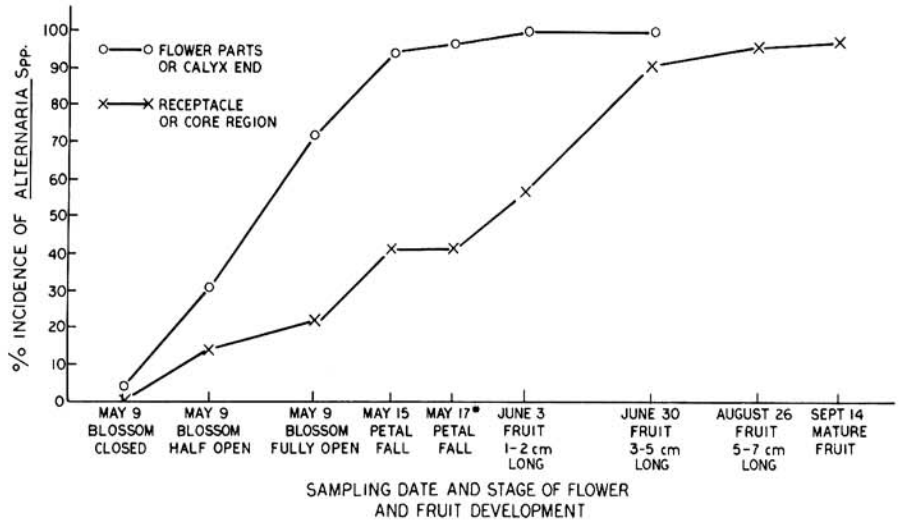

Fig. 4. Mean percentage incidence of *Alternaria* spp. recovered from flower parts (samples collected before 3 June) or calyx ends (samples collected after 17 May) and respective receptacles (collected before 3 June) or core region (collected after 17 May) of Delicious fruits collected at various stages of development in 1981. The 17 May sample was collected one day after petal fall spray (16 May).

in the core region was almost always that of *Alternaria* spp. *A. alternata* was the most prevalent species.

Data for colonization of flower parts and core regions were very similar for both years tested (Figs. 3 and 4). *Alternaria* spp. colonized flowers and young fruit very early in the season. Shortly after the petals opened, *Alternaria* appeared to move into flower parts (stamens, sepals, petals, and portions of the pistil). By petal fall (1981), more than 90% of the flowers were colonized by *Alternaria* spp. On 3 June 1981, 100% of all calyx ends plated were colonized by *Alternaria* spp. Movement into the ovary or core region rapidly followed colonization of flower parts. By petal fall (1981), *Alternaria* spp. was recovered from the receptacle (containing the ovary) of 41% of the fruit; by 3 June, 57% of all fruit had *Alternaria* spp. in the core region; and by 30 June, more than 90% of the core regions were colonized. The mean percentage incidence of moldy-core at harvest over all treatments was 38 and 66% for 1980 and 1981, respectively. In both years, almost 100% of the fruits were colonized by *Alternaria* spp. Although most fruits were colonized by *Alternaria*, not all developed moldy-core symptoms. The reason for this is not known.

Fungicide treatments had no effect on colonization of flower parts and core regions by *Alternaria* spp. or on the percentage of visible moldy-core at harvest in both years of testing. In 1981, flowers were collected immediately before the petal fall spray and again 2 days later. There were no significant differences in recovery of *Alternaria* spp. from any of these flowers. Two years of fungicide testing for control of moldy-core in Ohio and West Virginia resulted in no significant level of control (*unpublished*). The results of these tests will be published in Volume 38 of *Fungicide and Nematicide Tests.*

Brown and Hendrix (2) reported that bloom sprays with several fungicides significantly reduced the incidence of core rot caused by *Alternaria* spp. and *Phoma* spp. During 2 yr of testing, however, with a wide variety of fungicides in full season programs including bloom sprays, we did not find a treatment that provided satisfactory control of moldy-core.

None of the fruit tested in this study showed external signs of rot, and all visible mycelia appeared to be restricted to within carpel walls. Rotting of tissues outside the carpel wall was rarely observed. The effects of moldy-core on apple fruit in storage were not considered in this study but need to be determined.

The results of this study suggest that *Alternaria* spp. are extremely common in the apple orchard and are closely associated with moldy-core. They apparently colonize flower parts and eventually grow (presumably through the open calyx tube) to the core or carpel region of almost all Delicious fruits. For some reason, only some fruits develop the moldy-core symptom (visible mycelia in the core). Moldy-core is an economically important problem affecting apple fruit quality. At present, there appears to be no satisfactory means of control.

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